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The present Rule 205(g) (1) of Chapter 2 of the Illinois Pollution Control Board's Regulations limits organic material emissions from: (a) any catalyst regenerator of a petroleum cracking system; or (b) any petroleum fluid coker; or c) any other waste gas stream from any petroleum or petrochemical manufacturing process; to 100 parts per million (ppm). The proposed amendment basically gives the operator of the organic material source the option to meet the less stringent requirements of Rule 205(f). Rul2 205(f) requires that the source meet the emission limitation of either 8 pounds per hour or reduce the uncontrolled organic emissions by at least 85 percent provided that there will be no increase in emissions from such sources above the level of emissions in existence on the effective date of R77-3.

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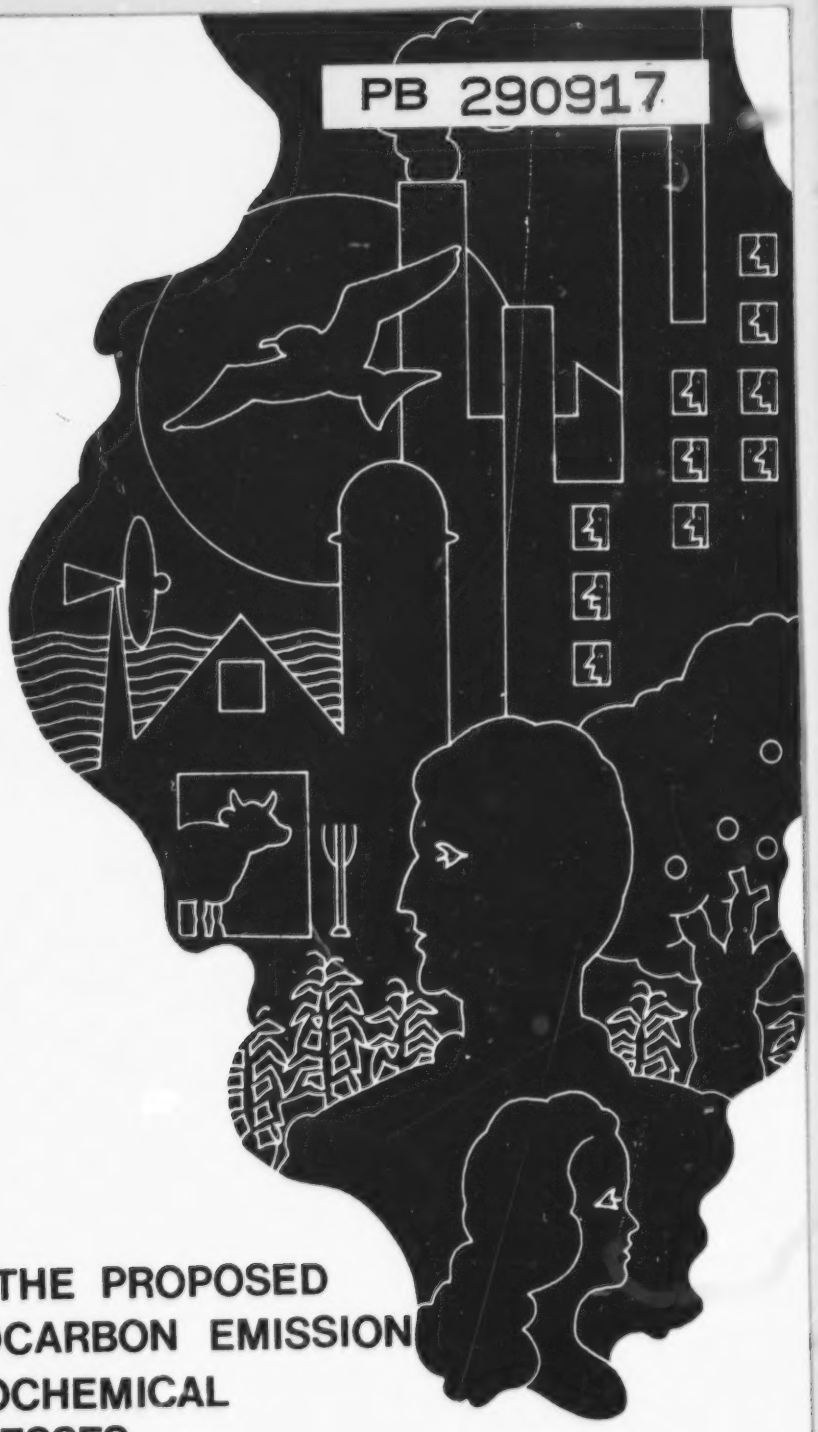

ECONOMIC IMPACT OF THE PROPOSED CHANGE IN THE HYDROCARBON EMISSION LIMITATION FOR PETROCHEMICAL MANUFACTURING PROCESSES

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ECONOMIC IMPACT OF THE PROPOSED CHANGE IN THE HYDROCARBON EMISSION LIMITATION FOR PETROCHEMICAL MANUFACTURING PROCESSES (R77-3)

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NOTE

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Opinion of the Economic Technical Advisory Committee
of the Illinois Institute of Natural Resources

The Economic Technical Advisory Committee has reviewed the economic impact study Document No. 78/30, entitled Economic Impact of the Proposed Change in the Hydrocarbon Emission Limitation for Petrochemical Manufacturing Processes, R77-3. The Committee finds the report to be generally responsive to the requirements of Section 6 of the Environmental Protection Act and recommends that it be forwarded to the Pollution Control Board so that public economic impact hearings may be held in conjunction with proposed regulation R77-3, ORGANIC MATERIALS, which seeks to amend Rule 205 of Chapter 2, Air Pollution Regulations.

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Executive Summary

The proposed amendment allows operators of any petroleum or petrochemical manufacturing process, other than petroleum fluid cokers and catalyst regenerator of petroleum craking systems, the option to meet the hydrocarbon emission limits specified in Pollution Control Board rule 205(g)(1) or 205(f). At present, these sources must comply with Rule 205(g)(1) which restricts sources to a maximum emission of 100 parts per million. Rule 205(f) would allow sources to meet a less stringent emission limitation of 8 lbs. per hour or to reduce emissions by at least 85%, provided there will be no increase in emissions from such sources above the level of emissions in existence on the effective date of R77-3.

There are 58 plants containing 807 hydrocarbon emission sources in Illinois affected by R77-3. Figure 3-1 shows the location and existing emission levels of these sources by county. Ninety-four of the 807 sources were analysed using IEPA permit data to determine control cost factors, average required emission reductions and air quality impacts. The analysis indicated that under the present Rule 205(g)(1), 394 of the 807 sources would be out of compliance. Under R77-3, 31 sources will be out of compliance.

The capital expenditure for control equipment required to meet the 100 ppm standard is estimated to be $83 million more than that required to meet the proposed Rule R77-3. Similarly, the net annual operating cost associated with the 100 ppm standard is $26 million more than that

which would be required with R77-3. The capital equipment cost and the remaining net annual operating costs associated with R77-3 are estimated to be $7 million and $2 million, respectively.

If these costs were passed through the consumer of products from the affected industries, projected price increases would range from 1.1% to 0.04%. Table 3-7 indicates the estimated price changes by standard industrial classification.

The passage of R77-3 would result in larger emissions of hydrocarbons than resulting from the enforcement of present regulations. Table E-1 shows the percentage change in emissions from present levels if Rule 205(g)(1)(c) were enforced or if R77-3 were passed.

These emission changes are translated into air quality impacts; an examination of the ozone monitoring data shows that there has been an increase in the second highest hourly ozone levels reported in Illinois in the past 3 years. Although the trend in ozone levels is the cause for concern, the air quality analysis of the <u>difference</u> in the impact between the 100 parts per million rule and R77-3 indicates that the more stringent regulation does not have a significant impact on air quality. The effect of increases in hydrocarbon emissions on the ozone levels was determined using Empirical Kinetic Modeling Approach (EKMA). Even by using "worst case" assumptions, the only counties experiencing more than 3% increase in ozone levels due to the passage of R77-3, are Clark and Marshall counties (Tables 2-1 and 2-2). A maximum increase in Clark County of 0.004 parts per million in ozone concentration would occur if R77-3 were promulgated. An investigation of past epidemiological effects of ozone levels failed to reveal any measurable health effects for such small increases.

Recent changes in the Clean Air Act (August, 1977 amendments) require Illinois along with other States to incorporate RACT (Reasonably Available Control Technology) emission limitations into a revised State Implementation Plan. The RACT document for Organic Chemical Manufacture Process Streams is scheduled for publication in December, 1978 and will very likely lead to revisions in the Illinois State Implementation plan. The IEPA emission standards for these types of sources will not be finalized until after publication of this document, therefore adoption of R77-3 will probably be an interim measure.

SUMMARY OF ECONOMIC IMPLICATIONS OF R77-3

1.	Number of potential affected sources	807
2.	"Out of Compliance" sources	
	- Present regulations	394
	- Proposed regulations	31
3.	Reduction in HC emissions assuming complete compliance with	
	- Present regulations	12,250 tons/yr
	- Proposed regulations	8,160 tons/yr
4.	Incremental cost difference between the present regulation and R77-3	
	- Capital cost	$83 million
	- Annualized operating cost	$26 million
5.	Cost effectiveness	$2,000 annualized cost/ annual ton of HC reduction
6.	Anticipated change in environmental quality	Negligible

1.0 Introduction

1.1 Motivation for the Proposed Regulation Change

The present Rule 205(g)(1) of Chapter 2 of the Illinois Pollution Control Board's Regulations limits organic material emissions from: a) any catalyst regenerator of a petroleum cracking system; or b) any petroleum fluid coker; or c) any other waste gas stream from any petroleum or petrochemical manufacturing process; to 100 parts per million (ppm). The proposed amendment basically gives the operator of the organic material source the option to meet the less stringent requirements of Rule 205(f). Rule 205(f) requires that the source meet the emission limitation of either 8 pounds per hour or reduce the uncontrolled organic emissions by at least 85 percent provided that there will be no increase in emissions from such sources above the level of emissions in existence on the effective date of R77-3. This option will also apply to new sources.

The proponents of R77-3 claim that most industrial processes utilizing or producing organic materials emit organic materials in excess of the 100 ppm level permitted by Rule 205(g)(1). Therefore, these sources are in violation of this Rule despite the fact that they may comply with the mass emission limitation of Rule 205(f). The proponents claim that although the existing emission limitation of Rule 205(g)(1)(c) may be appropriate for certain major organic material emission sources located within petroleum refineries, such a limitation, when applied to processes which merely manufacture or use organic chemicals, imposes unnecessarily stringent and costly control requirements. They believe that in lieu of

the present concentration-based limitation of Rule 205(g)(1)(c) for such processes, the pound-per-hour or percent-control limitations of present Rule 205(f) are appropriate and economically reasonable. The proponents also contend that the amendment will make the limitations applicable to organic emissions from petrochemical manufacturing operations or processes consistent with those applicable to other emission sources of organic material.

1.2 IEPA Position

The Illinois Environmental Protection Agency supports R77-3 for several reasons. At the present time the Agency is preparing an evaluation of hydrocarbon control measures to reduce emissions from stationary and mobile sources in Illinois. It is anticipated that those sources termed petrochemical manufacturing facilities will need controls but the requirements may differ from those currently required by Rule 205(g)(1)(c). It is the Agency's assessment that the current 205(g)(1)(c) rule is not equitable and requires a high degree of control for only a portion of the population of sources even within an affected facility. In addition, any emission limitation should be phrased in a manner to prevent circumvention by dilution and should take cognizance of the United States E.P.A. policy on photochemical reactivity.

The Agency's assessment is that the current photochemical oxidant levels and trends indicate the present State Implementation Plan is inadequate with respect to hydrocarbon control. The Agency is currently evaluating alternative hydrocarbon control strategies. In addition, recent changes in the Clean Air Act (August, 1977 amendments) require

Illinois along with other states to incorporate RACT* emission limitations into a revised State Implementation Plan in an orderly fashion. The RACT document for Organic Chemical Manufacture Process Streams is scheduled to be available in December, 1978. This document will very likely lead to revisions in the Illinois State Implementation Plan. However, the Agency proposals for these types of sources will not be finalized until the RACT document has been analyzed and will provide for an orderly compliance schedule.

As of December, 1977, the U.S. EPA has released 10 RACT documents. The Agency has submitted proposed regulations incorporating these 10 RACT documents to the Pollution Control Board (R78-3 and R78-4).

The Agency supports the proposed rule since there will be no additional emissions from existing sources and there may be reductions required in some cases. The rule could result in reductions of emissions from new facilities since all organic emissions, not just photochemically reactive material, would be covered. In the interim period before specific controls are proposed for the organic chemical manufacture category, this rule would allow those affected existing sources to obtain operating permits and avoid the costs of further litigation and possible fines, etc., as well as meet new source review standards for non-attainment areas.

1.3. Principal Benefits of R77-3

The primary benefit of R77-3 is the reduction in control equipment cost which would otherwise be required to meet the present 100 ppm

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*Reasonably Available Control Technology (RACT).

emission limitation. Section 3 presents a detailed estimate of the expected savings in control equipment cost which may result from passage of R77-3.

1.4. Significant Cost Elements

The most significant cost element is the increase in the ambient ozone level which would result from the increase in hydrocarbons in some areas. Although the increase in ozone would be small or negligible in all cases there will still be some effect on human health, animals, vegetation and materials. The translation of these effects into some dollar figure would be difficult for several reasons. The principal problem, however, is that there exists very little information, if any, on the direct effect of such small changes in the ozone concentrations.

To estimate what these changes in ozone concentrations might be for those counties with organic material emission sources affected by R77-3, two approaches were taken. These methods of analysis are the "probable case" which is based on a linear extrapolation of selected sample statistics and the "worst case" which is based on a possible set of conditions which maximizes the estimated hydrocarbon reduction which would occur with the existing regulation. This analysis is outlined in Section 2.0.

A review of the health related effects of ozone and the potential impact of the expected increases which will result from passage of R77-3 are presented in Section 4.0.

2.0 Current and Anticipated Environmental Consequences

Complete compliance with the present regulations will result in a reduction in the existing hydrocarbon emissions. Adoption of the proposed regulations will also result in a reduction in hydrocarbon emissions but these reductions will be less than those anticipated if the present regulation remained in effect. Therefore, the replacement of the 100 ppm emission limitation with R77-3 would result in a net "increase" in hydrocarbons if complete compliance is assumed.

This hydrocarbon increase is environmentally important primarily because of the role hydrocarbons play in ozone formation. It has been demonstrated that the ambient levels of ozone are directly related to gaseous hydrocarbon concentrations.[1] The percent increases in hydrocarbon emissions and the corresponding ozone levels which would result from passage of R77-3 are analyzed in Appendices B and E and are summarized in Table 2-1 for eight sample counties.

The reason for not including the other counties affected by R77-3 in the sample was the unavailability of source operating data. Information such as flow rate and temperature of the gas stream enables the calculation of allowable emissions based on the existing 100 ppm limitation. Without this information, a comparison between the anticipated changes in the existing hydrocarbon emissions resulting from the present and proposed regulations cannot be made. In the case of Grundy county, the required information was available for only one source out of a total of eighteen affected sources in that county. This source was found to be in compliance with the present and the proposed regulation and therefore no change in the hydrocarbon emissions was anticipated with complete enforcement of

Table 2-1

Effect of Hydrocarbon Emissions on Ozone Levels in Eight Sample Counties

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
				Worst Case[1]			Most Probable Case[1]		
County[2]	$\frac{NMHC}{NO_x}$ Ratio[3]	Design Value[3,4] for Ozone (ppm)	Nearest Ozone Monitoring Site[5]	Ozone Levels[6] (ppm)	Increase in HC Emissions[7] (%)	Increase in Ozone Levels (%)[8]	Ozone Levels[6] (ppm)	Increase in HC Emissions[7] (%)	Increase in O_3 Levels[8] (%)
Cook	7.0	0.261	Lake County	0.257	3.18	1.3	0.26	0.36	Negligible
Will	14.2	0.155	-	0.153	1.6[9]	0.6[9]	0.153	1.42	0.6
Jo Daviess	9.5	0.120	Winnebago	0.117	1.13	0.7	0.117	1.13	0.7
Peoria	9.5	0.126	-	0.124	1.66	0.6	0.124	1.37	0.6
St. Clair	9.5	0.144	-	0.144	0.35	Negligible	0.144	0.3	Negligible
Kankakee	9.5	0.155	Will	0.155	0.04	Negligible	0.155	0.04	Negligible
DuPage	9.5	0.136	- - -	0.136	1.29	0.3	0.136	0.09	Negligible
Clark	9.5	0.103	Champaign	0.101	10.41	3.9	0.101	10.41	3.9

1. Refer to the text in Section 2 for explanation of the worst and the most probable case.
2. Only those counties have been included for which enough information was available to carry out the analysis.
3. $NMHC/NO_x$ ratio and the design value for ozone are used in EKMA (Empirical Kinetic Modeling Approach) analysis to obtain the values in columns (4), (6), (7), and (9).
4. Design value is the second highest ozone concentration observed during the base period of one year (1977).
5. Applicable to only those cases where there is no ozone monitoring site in the county under consideration.
6. These are the anticipated second highest ozone levels calculated by means of EKMA assuming complete compliance with the existing regulation. These levels were estimated by considering the effects on column (2) ozone values, of the total reduction in the existing hydrocarbon emission if all sources met the 100 ppm emission limitation.
7. These values are the anticipated increases in hydrocarbon emissions associated with the change in regulations, the derivations of which are shown in Tables E-1 and E-2.
8. The increase in ozone levels are calculated by using the EKMA technique which required the $NMHC/NO_x$ ratio, the design value for ozone, and the anticipated increase in hydrocarbon emissions as the input data. These are the increases resulting from the passage of R77-3 over the base ozone values in column (4) and column (7).
9. The validity of these values is questionable; further explanation appears in Appendix B.

either of the regulations. However, since estimating the results for all of the eighteen sources based on the results of one source could be misleading, it was decided not to use these results for calculating the effects on ozone levels in this county.

The computational details and the assessment worksheets for Table 2-1 are given in Appendices B and E. Column (2) in Table 2-1 gives the existing ozone levels in terms of the second highest value monitored in each county. Columns (4) and (7) show the anticipated second highest values for ozone assuming complete compliance with the existing regulations. The values are based on two alternative approaches: the "Most Probable" approach using a statistical correlation between the sample and the population to derive the overall results and the "Worst Case" analysis which presents the maximum possible increase in hydrocarbon emissions which could result from the passage of R77-3. Further explanation of these two approaches is presented in Appendix B. Columns (5) and (8) give the increase in hydrocarbon emissions expected from the passage of R77-3 over the anticipated levels assuming complete compliance with the present regulations. Columns (6) and (9) give the corresponding anticipated increase in ozone levels over the values in columns (4) and (7).

Table 2-2 gives information on the present ozone levels and the hydrocarbon emissions in counties not included in the sample. The last column in the Table gives the maximum possible reductions in hydrocarbon emissions assuming that the emissions from the affected sources could be completely eliminated by enforcing the existing regulations. This hypothetical case is not realistic, but if the change in hydrocarbon emissions is insignificant for the greatest possible reduction, then

Table 2-2

Hydrocarbon Emissions and Ozone Levels for Other Affected Couties Not Included in the Sample

County	(1) Number of Affected Sources	(2) Design Value for Ozone[1] ppm	(3) Nearest Ozone Monitoring Site[2]	(4) Hydrocarbon emissions from the affected Sources[3] (tons/yr.)	(5) Total Hydro-carbon emissions in the county[4] (tons/yr.)	(6) (4) as a Percentage of (5)
Kane	10	.136	DuPage County	122.0	23839	0.5
Marshall	62	.131	LaSalle County	1774.0	7248	24.5
Sangamon	18	.140	-	420.0	12649	3.3
LaSalle	13	.131	-	158.0	9710	1.6
Crawford	7	.103	Champaign County[5]	N.A.[6]	2626	-
McHenry	37	.261	Lake County	37.0	6467	0.6
Morgan	54	.140	Sangamon County	142.0	2809	5.0
Madison	14	.187	-	N.A.	46569	-
DeKalb	2	.165	-	1.0	4409	0.02
Rock Island	22	.146	-	108.0	13846	0.8
Douglas	11	.103	Champaign County	N.A.	1973	-
Winnebago	68	.120	-	13.0	12702	0.1
Grundy	18	.155	Will County	383.0	5788	6.6

1. Design value is the second highest concentration observed during the base period of one year (1977).
2. Applicable to only those cases where there is no ozone monitoring site in the county under consideration.
3. Total existing hydrocarbon emissions from the plants affected by R77-3 were made available by the IEPA.
4. Total hydrocarbon emissions by county including stationary and mobile sources were made available by the IEPA.
5. There is no ozone monitoring site in the Crawford County or in its vicinity. The ozone monitoring site in Champaign County was taken to be the nearest site for the purposes of this analysis.
6. Not available.

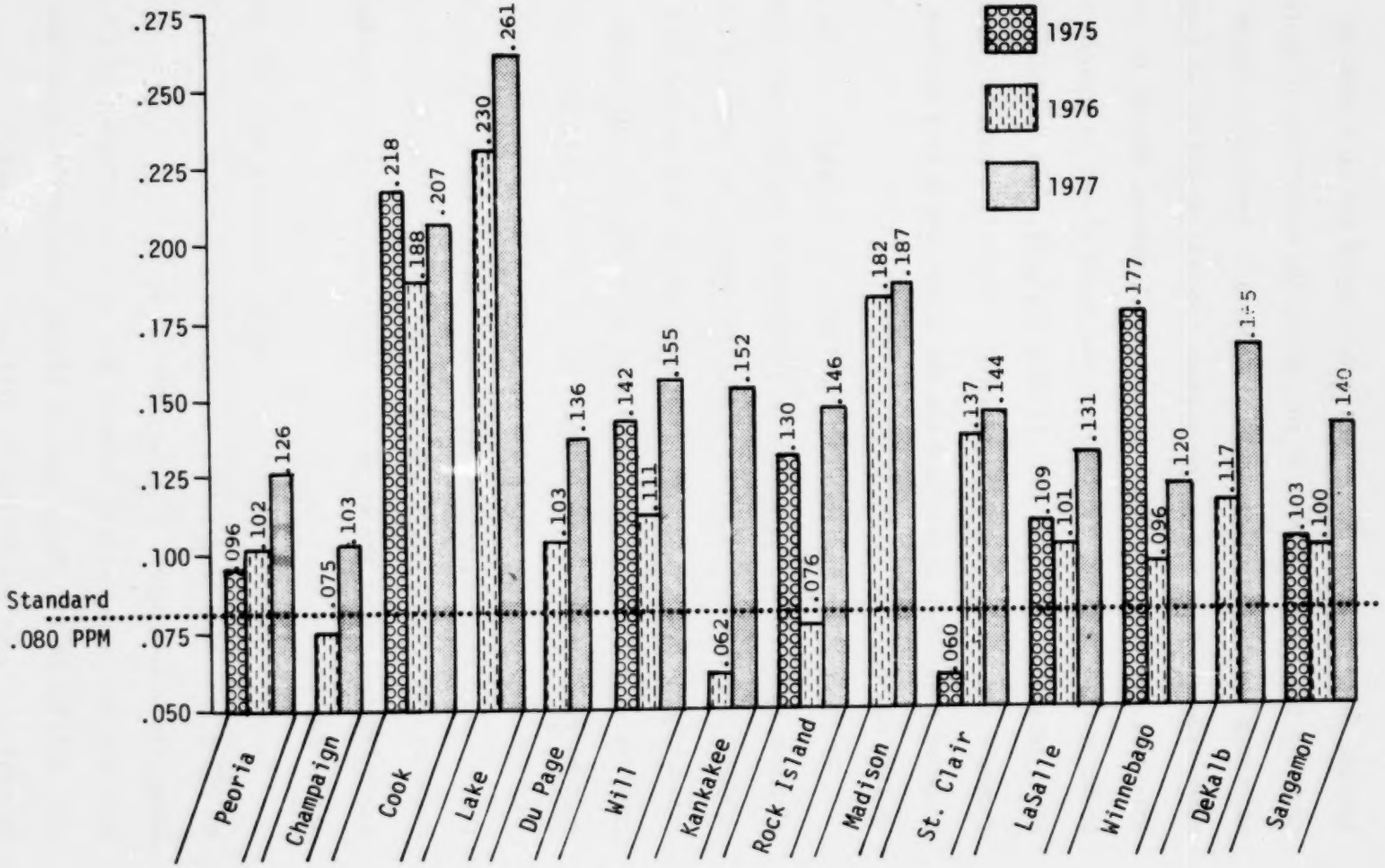
leaving these counties out of the sample would not be a problem. As shown in the Table, in most of the cases, the reductions in hydrocarbon emissions obtained are too small to cause any significant change in the ozone levels. Even though the maximum possible reduction in hydrocarbon emissions are 3.3, 6.6, and 5 percent for Sangamon, Grundy and Morgan Counties respectively, these reductions would result in changes in the ozone levels of less than 2%. In this analysis, only Marshall County showed a significant increase in ozone. There is a possibility that the proposed regulation could increase the ozone levels by a maximum of 9% in this county.

As the results in Table 2-1 and Table 2-2 indicate, all the counties affected by R77-3 are currently in violation of the proposed Primary National Ambient Air Quality Standard for ozone (the proposed Secondary Standard remains at 0.08 ppm). In addition, it is expected that all the counties will remain in violation even with complete enforcement of the present regulation. Based on the results in Table 2-1, the expected increase in ozone concentrations associated with the replacement of present regulation with R77-3 is below 0.004 ppm for all the counties. Clark is the only county which shows over 2 percent increase in ozone concentrations under the worst case conditions, which as previously stated are highly unlikely.

Based on the above results, it can be concluded that the imposition of R77-3 will lead to a slight degradation of air quality. Figure 2-1 shows the actual second highest ozone concentrations in various counties over the last three years. Some of the counties affected by R77-3 are not included in the Figure because either there was no ozone monitoring in that county or the monitoring data were incomplete.

Figure 2-1

Annual Second Highest Hourly Ozone Levels for Selected Counties (1975-1977)



Source: Data provided by Illinois EPA

3.0 Benefits

The primary benefit of replacing present regulations with R77-3 is the reduced control equipment cost. The control costs are estimated based on the number of sources which are in compliance with the proposed regulations but which would need control equipment under the existing regulations. Compliance with the existing standards is checked by comparing the actual hydrocarbon emissions with the allowable emissions based on 100 ppm limitation for each source. Compliance with the proposed regulations requires either 85 percent control of the hydrocarbon emissions from the source or a maximum emission of 8 lbs./hr. of hydrocarbons.

3.1 Plants Affected by R77-3

There are 807 sources in 58 plants which are subject to rule 205 (g)(1)(c). These sources are located in 21 different counties with Cook County accounting for approximately 36% of the sources.

Figure 3-1 shows the location of various affected counties in the State, the number of plants and the sources affected by the regulation in each county, and the level of hydrocarbon emissions from these sources. The counties included in the sample for analysis are shown as shaded regions.

The main consideration in determining whether or not a plant or source would be included in the sample was the availability of operating information. Operating conditions like flow rate and temperature values were required to calculate the allowable emissions based on the 100 ppm standard. Also, the actual hydrocarbon emissions were needed for comparison with the allowable emissions. Based on the above considerations and the available information from IEPA, 94 sources in 17 plants could be included

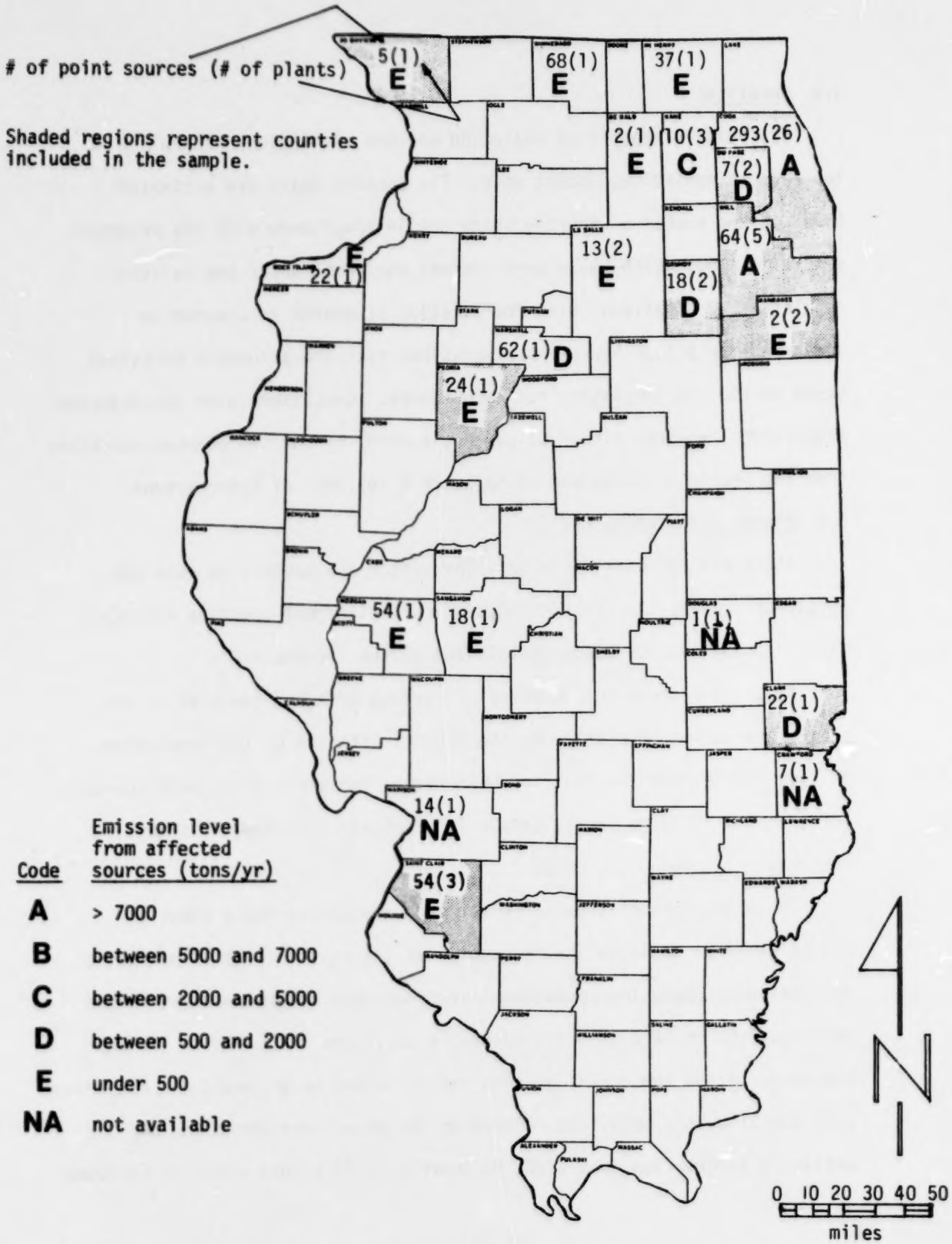


Figure 3-1 Hydrocarbon Emissions from Sources Subject to R77-3

in the sample. Appendix B gives further details about the selection of sample and compares it with the total population.

3.2 Estimation of Hydrocarbon Emissions and "Out of Compliance" Sources

To check the compliance of affected sources with the existing and/or proposed regulations, it was required to calculate the actual and allowable hydrocarbon emissions on a source-by-source basis. It was not possible to do this for all the sources individually because of insufficient operating data for many sources, as previously mentioned.

The methodology for arriving at the population estimates for out of compliance sources and their hydrocarbon emission patterns are described in Appendix B. Two alternative approaches were used to estimate the overall results from the sample statistics. The most probable approach assumes the sample to be a complete representative of the population and all the population estimates are based on the sample results. Under the worst case conditions, the results for sources in the sample are based on the actual data contained in the emission inventory and, for other affected sources not included in the sample, the analysis is carried out in a manner to maximize the increase in hydrocarbon emissions resulting from the passage of R77-3. A detailed explanation of these approaches is included in Appendix B. For the purposes of estimating control costs, the results of "most probable" approach are considered. Results of the "worst case" analysis are used in Chapter 4 to estimate the worst possible effects on environmental quality.

3.3 Control Cost Estimates

The following assumptions and simplifications were made in estimating the total control equipment costs.

1. The only control technology options considered are carbon adsorption, absorption, incineration (thermal and catalytic) and indirect condensation. The extent of control achieved through each of the above options has been assumed to be 90 percent based on their average control efficiencies in industrial applications. Appendix C gives a brief discussion of the control technology and the relative effectiveness of each control option.

2. It was required to have the flow rate of the inlet stream, the inlet temperature of the gas to the control device, the quantity of hydrocarbons to be controlled, and the hours of operation to estimate the capital and operating costs of the control devices. Since these input data were not available for all the out of compliance sources individually, it was decided to group them into the following five categories based on the process technology.

1. Reactors
2. Reducing tanks, stills, cooking kettles, etc.
3. Absorption, recovery, condensation, distillation towers, etc.
4. Mixing tanks
5. Miscellaneous (vents, jets, etc.)

The operating conditions and the reduction in hydrocarbon emissions required for each of the categories were based on the average value for each source category in the sample. A summary of these average values is presented in Table 3-1.

3. The cost estimates for each control option were developed based on the guidelines provided in the Manufacturing Chemists Association's

Table 3-1

Average Operating Conditions and Reduction in Hydrocarbon Emissions by Source Category[1]

Source Category	Number in the Sample[2]	Average Values Based on the Sample Information[1]			
		Flow rate (ACFM)	Temperature (^{o}F)	Hours of Operation in a Year	Average Reduction in HC Emissions[3] per Source (lbs./hr.)
Reactors	52	15850	330	7420	15.92
Reducing Tanks/Stills	12	8230	100	5710	20.69
Recovery Units	16	400	100	7680	15.38
Mixing Tanks	6	400	100	5900	20.02
Miscellaneous	8	9940	260	5530	21.36

1. The calculations are based on the emission inventory data presented in Table B-2 of Appendix B. For example, the average flowrate for the reactor source category was calculated from the actual flowrate data for the reactors included in the sample of 96 sources in Table B-2.

2. These numbers were found by arranging the sample sources (included in Appendix B-2) by source category.

3. These values are based on the reduction in hydrocarbon emissions required to comply with the existing regulations. The required reduction per source is approximately 59 tons/yr.

final report on Cost of Hydrocarbon Emissions Control to the U.S. Chemical Industry (SIC 28). The generalized cost curves given in the report were used to estimate the approximate capital costs for each control option considered. Appendix D gives the outline for the background technical calculations and the procedure for estimating capital and operating costs. The selection of control equipment is based on the existing control practices for various source categories as analyzed from the sample information taken from IEPA inventory data. The details of these analyses are given in Appendix D.

The following comments can be made concerning the control equipment costs for the sources which are out of compliance with the existing standards and would be in compliance with R77-3.

1. Under the present regulations, there are 394 out of compliance sources based on a population of 807 affected sources. Under the proposed regulations, only 31 sources are out of compliance. Therefore passage of R77-3 will eliminate the cost of controlling the additional 363 sources. (The detailed analysis is given in Appendix B).
2. The additional capital costs required to bring these 363 sources in compliance with the 100 ppm emission limitation are estimated to be $73.8 million. This cost is estimated in 1975 dollars. If an average rate of inflation of 6% is assumed for equipment cost, this figure comes to $83 million. The reduction in hydrocarbon emissions by applying this additional control technology is approximately 11 thousand tons per year which gives an estimated capital cost of about $7,500 dollars per

ton of reduction in hydrocarbon emissions (in 1978 dollars). Table 3-2 presents a summary of these results. As is evident, the capital cost per ton of reduction is highest for the Reactor Source Category and it accounts for the majority of the capital expenditure. The overall capital cost per ton of reduction in hydrocarbon emissions is high because of the low concentration of hydrocarbons in the flue gases and the corresponding low absolute reduction in the hydrocarbon emissions.

3. The savings in annual operating costs for control equipment resulting from the passage of R77-3 are estimated to be $28 million out of which $15 million are the direct operating expenses and the balance of $13 million account for depreciation, taxes and insurance. The value of recovered material is $5 million which gives a net annual operating cost of $23 million (approx. $26 million in 1978 dollars). Heat recovery was taken into account while calculating the total annual costs for each control technique. As is the case for the total capital cost, the Reactor Source Category accounts for a majority of the operating cost expense. This is primarily due to the high average flow rate of gas stream and the hours of operation as indicated in Table 3-1. The net annual operating costs per ton of reduction is approximately $2,000. A summary of these results is presented in Table 3-3. Other associated costs of control such as the value of staff and management time and the value of production downtime were not included in the analysis.

Table 3-2

Estimated Capital Cost of Control Equipment Eliminated by the Passage of R77-3[1]

	Emission Source Category					
	Reactors	Reducing Tanks/Stills	Recovery Units	Mixing/ Blending	Miscel- laneous	Total
Number of Installations[2]	207	87	35	17	17	363
Capital Cost ($ million)[3]	56.5	10.7	2.0	0.9	3.7	73.8
Capital Cost per Installation ($ thousands)	273.0	123.0	57.0	53.0	218.0	203.0[4]
Hydrocarbon Emission Level Before Control (thousand tons/yr.)[1,5]	7.2	3.0	1.2	0.6	0.6	12.6
Hydrocarbon Emission Level After Control (thousand ton/yr.)[1,5]	0.74	0.31	0.1	0.06	0.06	1.3
Hydrocarbon Emission Level Reduction (thousand ton/yr.)	6.5	2.7	1.1	0.5	0.5	11.3
Capital Cost per Ton Reduction ($ thousands/ton)	8.7	4.0	1.8	1.8	7.4	6.5

1. Includes only those sources which are in compliance with the proposed regulations and need control equipment under the existing regulations.
2. Represents the number of sources needing control equipment as given in Table D-3.
3. Based on the capital cost analysis done for each control technique and for all the source categories by the procedure outlined in Table D-1.
4. This is the average capital cost per installation for all the sources needing control equipment.
5. Based on the average hydrocarbon emissions per source analyzed in Appendix B, Table B-4. The hydrocarbon emissions before control correspond to the actual emissions in Table B-4 (13658.5/394 = 34.67 tons/yr/source) and emission level after control corresponds to the allowable emissions in Table B-4 (1406.0/394 = 3.57 tons/yr./source).

Note: These costs are in 1976 dollars.

Table 3-3

Estimated Annual Operating Cost of Control Equipment Eliminated by the Passage of R77-3[1]

	Emission Source Category					
	Reactors	Reducing Tanks/Stills	Recovery Units	Mixing/ Blending	Miscel-laneous	Total
Number of Installations[2]	207	87	35	17	17	363
Annual Operating Cost ($ million)[3]	12	2	0.3	0.2	0.7	15.2
Value of Recovered Material[4] (credit) ($ million)	(3.2)	(1.3)	(0.4)	(0.3)	(0.1)	(5.3)
Operating Cost Minus Recovered Material	8.8	0.7	(0.1)	(0.1)	0.6	9.9
Depreciation, Taxes Insurance ($ million)[5]	10.2	1.8	0.3	0.2	0.7	13.3
Net Annual Operating Cost ($ million)	19.0	2.6	0.2	0.1	1.3	23.2
Net Annual Operating Cost per Ton Reduction[6] (thousands/ton)	2.9	1.0	0.2	0.2	2.6	2.1[7]

1. Includes only those sources which are in compliance with the proposed regulations and need control equipment under the existing regulations.
2. The number of installations needing control equipment in each source category are estimated in Table D-3.
3. Based on the operating cost analysis done for each control technique and for all the source categories by the procedure outlined in Table D-1.
4. Calculated by assuming that 90 percent of the hydrocarbons controlled by the control equipment are recovered. The total reductions in hydrocarbon emissions achieved for each source category by the use of control equipment are given in Table 3-1. The average price for hydrocarbon is assumed to be $0.15/lb. The value of recovered material was calculated on yearly basis by using the average hours of operation per year for each source category (given in Table 3-1).
5. Estimated at 18 percent of the capital cost. Capital costs are given in Table 3-2.
6. Reduction in hydrocarbon emissions for each source category are taken from Table 3-2.
7. This is the average net annual operating cost per ton reduction for all the sources needing control equipment.

Note: These costs are in 1976 dollars.

4. The total capital expenditures for control equipment required to meet the proposed regulation R77-3 are approximately $7 million in 1978 dollars (31 "out of compliance" sources). The net annual operating costs associated with the operation of these additional control equipment are approximately $2 million (in 1978 dollars). These figures are derived from the results of the incremental cost analysis (Tables 3-2 and 3-3) and are based on the ratio of "out of compliance" sources (31 sources/363 sources).

5. The operation of hydrocarbon emission control equipment will require an estimated 208.4 thousand equivalent barrels of oil annually to control the emissions of the sources which are out of compliance with the existing regulations and in compliance with the proposed regulations. (See Table 3-4).

3.4 Control Costs Summary by Standard Industrial Classification

The seventeen Illinois Plants included in the sample analysis can be classified in one of the following seven three digit categories:

281: Industrial inorganic chemicals
282: Plastics materials, synthetics
284: Soaps, cleaners, toilet goods
285: Paints and allied products
286: Industrial inorganic chemicals
287: Agricultural chemicals
289: Miscellaneous chemical products

To estimate the control costs by SIC category, the 94 sample sources (included in 17 plants) were classified in various SIC categories based on their process characteristics and the end-product manufactured. The relative proportion of the sample sources in each SIC category was used to break up the total incremental capital and operating costs (Tables 3-2 and 3-3) by SIC category in Illinois. These costs are summarized in Table 3-5.

Table 3-4

Additional Energy Requirements for Control Equipment Eliminated by the Passage of R77-3[1]

	Requirements[2]	Thousand Equivalent Barrels of Fuel per Year[3]
Fuel (billion BTU/yr.)[4]	235	37.4
Electricity (millions KWH/yr.)	315	171.0
Steam (thousands lbs./yr.)	90	0.02
Total		208.42

1. Includes only those sources which are out of compliance with the existing regulation and in compliance with R77-3.
2. Based on the energy requirements for the individual source categories and the available control technologies as analyzed by procedure outlined in Table D-1.
3. The following basis has been used for conversion to barrels of fuel:
   - 6.287 million BTU per barrel of residual fuel oil
   - 1,842 KWH per barrel of residual fuel oil
   - 5,030 pounds of steam per barrel of oil

   (source: "Cost of Hydrocarbon Emissions Control to the U.S. Chemical Industry", Manufacturing Chemists Association, 1976).
4. Heat recovery has been taken into account.

Table 3-5

Capital and Annualized Cost by SIC Category

SIC	Capital Cost ($ million)	Annualized Cost ($ million)
281	5.8	1.8
282	2.3	0.7
284	6.8	2.1
285	21.5	6.7
286	17.4	5.5
287	6.2	2.0
289	0.9	0.3
Miscellaneous*	22.1	6.9
	83.0	26.0

* Includes the cost information on other sample sources which could not be classified into one of the above SIC categories.

NOTE: Cost figures are in 1978 dollars.

3.5 Industrial Price Impacts

The impact of the above control costs on Illinois industry is presented in terms of the new capital investments to annual sales ratio. This ratio reflects the relative economic growth or decline of the industries affected by R77-3. By comparing this ratio with the same ratio for the industries nationally, it is possible to see whether these Illinois industries are growing faster, more slowly, or at the same rate as their counterparts in the rest of the nation. This comparison by SIC category is given in Table 3-6.

Two indices are employed to assess the relative impact of additional compliance costs on Illinois prices and employment. The direct price impact to consumers is indicated by the ratio of annualized compliance costs to annual value of shipments (Table 3-7). These percentages could represent price increases if it is assumed that the full cost of the additional control equipment is passed on to the consumers of affected products.

Another impact index is the ratio of capital costs required for compliance to annual new capital spendings. This index reflects a capital budgeting impact approach to the problem of how R77-3 will affect Illinois industry. If an industry is spending a percentage of its capital budget on environmental equipment, that amount is not available for equipment replacement or plant expansion. Thus, for example, a 50 percent figure indicates that the compliance requirements would consume one half of one year's normal capital expenditures for new plants and equipment. Table 3-8 gives the ratio of Capital Compliance Costs to New Capital Expenditure for affected SIC categories in Illinois.

Table 3-6

New Capital Investment to Sales Ratio by SIC Category

SIC	Illinois New Capital/Sales (Percent)	U.S. New Capital/Sales (Percent)
281	6.76	5.44
282	10.90	7.08
284	3.07	2.41
285	2.63	2.13
286	7.97	7.17
287	1.64	3.97
289	3.31	3.53

Source: 1972 Census of Manufacturers and 1972 Census of Mineral Industries.

Table 3-7

Annualized Compliance Costs to Illinois Sales Ratio

by SIC Category

SIC	Annualized Compliance Cost/ Illinois Sales (Percent)
281	0.5
282	0.2
284	0.1
285	0.9
286	1.1
287	1.0
289	0.04

Source: 1972 Census of Manufacturers and 1972 Census of Mineral Industries (1972 "value of shipments" figures updated to June, 1978, by CPI inflator of 55.9%).

Table 3-8

Capital Compliance Costs to New Capital Expenditures Ratio by SIC Category

SIC	Capital Compliance Costs/New Capital Expenditures in Illinois (Percent)
281	23.5
282	5.1
284	10.3
285	103.7
286	45.2
287	189.4
289	3.7

Source: 1972 Census of Manufacturers and 1972 Census of Mining Industries (1972 "new capital expenditures" figures updated to June, 1978, by CPI inflator of 55.9%).

4.0 Costs

The adoption and enforcement of R77-3 would result in a higher ambient ozone concentration than the level which would result from strict compliance with the existing regulation. However, even under the worst case conditions which are highly improbable, the only counties which will be subjected to an increase of more than 2 percent in the ozone levels because of the adoption of R77-3 are Clark and Marshall counties. The maximum increase in the ozone levels in Clark county in absolute value is less than 0.004 ppm. (See Figure 2-1 for indication of present levels). Even a small increase in ambient ozone concentrations will have some adverse environmental effects. These adverse effects on environmental quality represent the "cost" of the proposed regulation which is not easily translated or expressed in dollar terms even for relatively large increases in ambient levels of ozone.

There are essentially no data to assess the health and ecological impacts of very small changes in ozone concentrations. Even though the health impacts which would result from the passage of R77-3 cannot be quantified, Sections 4.1 and 4.2 review the current ozone effect information at several exposure levels.

4.1 Health Impact

4.1.1 Population Impacted

It is estimated that approximately one million people (Table 4-1) throughout the state will experience a greater than negligible increase in ozone concentration under the most probable case. This is roughly 10% of the total population of the State. Under the worst case assumption, approximately 7.5 million (Table 4-1) will experience a greater than

Table 4-1

Estimate of Population Impacted by R77-3

	Worst Case				Most Probable Case			
Increase in Ozone Concentration	Number of People	Number of People 15 and Under	Number of People 65 and Over	Number of Non-Whites	Number of People	Number of People 15 and Under	Number of People 65 and Over	Number of Non-Whites
Greater than Negligible	7,531,405	2,188,928	688,619	1,311,088	1,009,731	308,345	105,057	53,274
3% or Greater	33,985	9,145	6,500	19	33,985	9,145	6,500	19

Note: The values in this summary Table are taken from the detailed Tables F-2 and F-3 in Appendix F.

negligible increase. Under the worst case, a substantial fraction of the State population would experience a more than negligible increase. Appendix F gives the procedure used for estimating the population impacted by R77-3 based on the demographic data available from the Bureau of Census. Many of the affected people reside in Cook County where the ozone concentration under the proposed regulation is estimated to be 0.260 ppm as compared with 0.257 ppm if the existing regulation were 100% enforced. The actual 1977 measurement of the second highest level of ozone was 0.261 (see Table 2-1). The above population estimates lack the overall accuracy necessary for attaching much importance to projected differences in ozone concentrations of this magnitude. Of course, if a greater than negligible increase in ozone concentration causes even a relatively small increase in discomfort, it may be an important cost of the proposed regulation simply because of the large number of people affected.

4.1.2 Health Effects

A review of the health effects of a particular pollutant may include data derived from controlled human or animal experiments and epidemiology studies. In general, causality can be established via animal studies because dose/response relationships can be developed and confounding variables controlled. However, there is always the question of how to extrapolate results from animal studies to the human experience. In general, results from epidemiology studies cannot be used to establish causality because confounding variables may not be well-controlled. However, when epidemiology studies are properly designed and executed, the results can be directly applied to human experience in contrast to

animal studies. The data derived from controlled human exposures, when available, provide the best basis for assessing the human health effects of a pollutant, especially when a small change in ambient concentration is under evaluation. Controlled human exposure studies combine the advantages of animal and epidemiology studies without the disadvantages.

In recent years, several studies have been carried out which involve the controlled exposure of humans to ozone in environmental chambers. The results of these experiments are summarized in this section in terms of the development of symptoms, decrease in pulmonary function, and changes in blood biochemistry. These effects will be related to the proposed rule change (R77-3). In addition, a brief discussion will be presented concerning ecological effects. Ecological effects will be related to the proposed rule change also.

4.1.2.1 Controlled human exposure to ozone and development of symptoms: A summary of experiments involving human exposures to ozone is presented in Table 4-2. These experiments were controlled in that they were carried out under specified conditions of exposure in environmental chambers. It is important to note that the data in Table 4-2 refer to groups of subjects and give little indication of individual responses within groups. Examination of Table 4-2 shows that symptoms develop in normal as well as hypersusceptible subject groups after 2 hours of exposure to about 0.37 ppm ozone.

Because Table 4-2 contains group data, it is important to explore individual reactions where the appropriate data has been published. First, the reactions of hypersusceptible subjects will be elaborated. Hackney, et al[2] found that a 2 hour exposure of one asthmatic subject to

Table 4-2

Decrease in Pulmonary Function and Development of Symptons in Humans Exposed to Ozone in Environmental Chambers

Ozone Concentration (ppm)	Duration of Exposure (hr)	Number and Type of Subjects[1]	Exercise[2]	Number of Parameters of Pulmonary Function Tested[3]	Number of Parameters of Pulmonary Function Showing Significant Change[4]	Symptoms[5]	Reference[6]
0.20-0.25	2	10 H	yes	2	0	no	(2)
0.2 -0.25	2	22 H	yes	9	1	no	(3)
0.25	4	4 H	no	14	1	no	(4)
0.37	2	12 N	yes	4	4	yes	(5)
0.37	4	4 H	no	14	4	yes	(4)
0.37-0.41	2	18 H	yes	2	2	yes	(2)
0.50	4	4 N	no	14	5	yes	(4)
0.50	4	4 H	no	14	7	yes	(4)
0.60	2	24 N	yes	3	3	yes	(6)
0.60-0.80	2	11 N	no	6	3	yes	(7)
0.75	2	12 N	yes	4	4	yes	(5)
0.75	2	10 N	no	9	3	yes	(8)

1. N = Normal subjects, i.e., subjects with no history of cough, chest discomfort, wheezing, allergy or respiratory disease; H = hypersusceptible subjects, i.e. asthmatics, subjects with a history of cough, chest discomfort, wheezing associated with allergy or air pollution exposure.
2. Brisk walking or riding bicycle ergometer.
3. Includes two or more of the following: peak expiratory flow rate, forced vital capacity, single breath nitrogen test, thoracic gas volume, static and dynamic lung compliance, maximal midexpiratory flow rate, air resistance, total respiratory resistance, closing volume, diffusing capacity, forced expiratory volume, maximum static elastic recoil pressure, vital capacity residual volume, specific airway conductance.
4. $P \leq 0.05$. P = probability of control-exposure difference being due to chance.
5. Presence of one or more of the following symptoms: cough, sputum, substernal irritation, chest restriction, nasal discharge, laryngitis, dyspnea, wheezing, headache, fatigue, tracheal irritation, malaise, pharyngitis, pain in deep inspiration.
6. The numbers refer to reference numbers in Reference Section.

0.20-0.25 ppm ozone was sufficient to produce increased chest restriction and substernal irritation. It is too early to interpret this preliminary finding; however, if 1 hypersusceptible subject in a group of 10 hypersusceptible subjects developed overt symptoms, there is some indication that a significant number of respiratory-impaired people may react adversly to ozone levels below 0.25 ppm. At higher levels of exposure, Hackney et al[4] found that a 4 hour exposure of 4 hypersusceptible subjects to either 0.37 ppm or 0.5 ppm ozone resulted in substernal pain, cough, wheezing, and malaise in all subjects, these symptoms were severe enough to prevent adequate performance of normal tasks. Similarly, Hackney et al[2] found that a 2 hour exposure of another group of 18 hypersusceptible subjects to 0.37-0.41 ppm ozone produced clear incapacitation of four subjects.

Turning to the reactions of normals, Hazucha, et al[5] found that a 2 hour exposure of 12 normal subjects to either 0.37 ppm or 0.75 ppm resulted in substernal soreness, chest tightness, and cough in all subjects. Hackney et al[4] found that a 4 hour exposure of 4 normal subjects to 0.5 ppm ozone produced mild pharyngitis and substernal discomfort in some subjects. Ketcham, et al[6] found that a 2 hour exposure of 24 normal subjects to 0.6 ppm ozone produced cough, pain in deep inspiration, and chest pain. Young, et al[7] found that a 2 hour exposure of 11 normal subjects to 0.6-0.8 ppm ozone produced substernal soreness and tracheal irritation in 10 subjects. Bates, et al[8] found that a 2 hour exposure of 10 normal subjects to 0.75 ppm ozone resulted in substantial soreness and cough in most subjects while a few complained of pharyngitis and dyspnea.

4.1.2.2 Controlled human exposure to ozone and subsequent development of decreased pulmonary function: A summary of experiments involving human exposures to ozone is presented in Table 4-2. The data in Table 4-2 refer to groups of subjects and provide little indication of individual responses within groups. An important observation to make in Table 4-2 is that for subject groups, there are few parameters which reflect decreased pulmonary function at ozone concentrations $\leq$ 0.25 ppm; similarly, there are no reported symptoms for groups at these levels of ozone. However, at ozone exposure levels $\geq$ 0.37 ppm, symptoms do develop and decreased pulmonary function is reflected in a greater number of parameters. Concerning individual responses to ozone, Hackney et al[2] found that a 2 hour exposure of one asthmatic subject to 0.20-0.25 ppm ozone was sufficient to produce a statistically significant decrease in pulmonary function as reflected in 2 parameters of lung function (FEV_1, and FVC). This result may indicate that asthmatics and other pulmonary-impaired individuals may suffer losses of lung function at ozone levels below 0.25 ppm.

4.1.2.3 Controlled Human Exposure to Ozone and Alterations in Blood Biochemistry: A summary of changes in blood biochemistry following ozone exposure is presented in Table 4-3. At every concentration of ozone examined, $\geq$ 0.20-0.25 ppm, small but statistically significant human blood biochemical changes are evident. These alterations include: increases in red blood cell membrane fragility, serum vitamin E levels, lipid peroxidation, and activities of red blood cell glucose-6-phosphate dehydrogenase and lactage dehydrogenase; decreases in red blood cell reduced glutathione levels, hemoglobin concentration and activities of red blood cell acetylcholinesterase and serum glutathione reductase.

Table 4-3

Alterations in Blood Biochemistry of Humans Exposed to Ozone in Environmental Chambers

Ozone Concentration (ppm)	Duration of Exposure (hr)	Number and Type of Subjects[1]	Exercise[2]	Number of Blood Parameters Tested[3]	Number of Blood Parameters Showing Significant Change[4]	Reference[5]
0.20 - 0.25	2	10 H	yes	2	2	2
0.20 - 0.25	2	22 H	yes	10	6	3
0.37 - 0.4	unspecified	26 N	yes	7	4	9
0.37 - 0.41	2	18 H	yes	2	1	2
0.4	2	15 N	yes	9	5	10
0.5	2	unspecified	yes	unspecified	5	11
0.5	unspecified	6 N	yes	7	7	9
0.5	2 3/4	7 N	yes	9	8	12

1. See Table 4-2

2. See Table 4-2

3. Includes two or more of the following: hemoglobin concentration, hematocrit, reduced red blood cell glutathione concentration, red blood cell fragility, levels of 2,3-diphosphoglycerate, serum vitamin E levels, serum lipid peroxide levels; activities of red blood cell acetylcholinesterase, gluthathione reductase, glutathione peroxidase, gluscose-6-phosphate dehydrogenase, lactate dehydrogenase, serum glutathione reductase.

4. See Table 4-2

5. The numbers refer to reference numbers in the Reference Section.

While the magnitude of these alterations are small but statistically significant, the changes do reflect similar biochemical responses reported in animal studies. The short and long term human health significance, if any, of these alterations in blood biochemistry are currently unknown.

4.2 Ecological Effects of Ambient Ozone

There is a vast literature concerning the effects of ozone on plants. A brief review of the available literature indicates that plants can be significantly damaged by low concentrations of ozone. For example: a controlled chamber experiment involving the exposure of sweet corn to 0.10 ppm ozone resulted in a 35% reduction in yield; the yield of wheat exposed to 0.20 ppm ozone was reduced by 30%. There are many reports purporting to demonstrate crop injury or yield reduction due to ozone exposures as low as 0.05 ppm.[13]

The study of the pathological effects of ozone on free-ranging vertebrates has received little attention.[13] However, at least one study in the San Bernadino mountains (near Los Angeles) has shown that oxidant air pollution has not yet resulted in a reduction in the diversity of small mammal species.[13]

In general, ozone at ambient concentrations has little or no effect on microorganisms.[13]

4.3 Health Costs

Donald Gillette[14] has estimated the health costs from ambient oxidant exposures for 1973. Hourly ozone concentrations were measured at approximately 400 monitoring stations, and the estimated health costs were derived from data relating adverse health effects to hourly oxidant concentrations. Approximately 10% of the American population resided in

areas where the hourly primary standard for oxidants of 160 micrograms per cubic meter was exceeded more than 5% of the hours in the year during the 1971-73 period, while 67% lived where the hourly standard was exceeded at least once annually. The total annual health cost attributable to oxidants was estimated to range from 120 to over 240 million dollars in 1973.

Seskin[15] using data for 1973, found that there did not appear to be a significant relationship between photochemical oxidant readings, as measured by the maximum or average on any given day and the number of unscheduled visits on that day to three of the four departments at the main clinic (Pennsylvania Avenue) of a local group practice medical plan. These included the Urgent Visit Clinic and the Internal Medicine and Pediatric Departments. The only exception was for unscheduled visits to the Ophthalmology Department. In examining the data for 1974, the results were comparable since again a positive and statistically significant relationship was exhibited between the oxidant readings and the unscheduled visits to the Ophthalmology Department. In addition, a suggestive relationship between oxidant levels and utilization of the Urgent Visit Clinic was seen. This relationship was further supported by the results of an analysis involving oxidant pollution data monitored at another station. In looking at the results of the 1973-74 studies together, the magnitude of the association between unscheduled visits to the Ophthalmology Department and photochemical oxidant levels indicated that a 10% decrease in oxidant levels was related to 0.1 -4.3% decrease in unscheduled utilization of the Ophthalmology Department. The statistically significant 1974 result pertaining to the Urgent Visit Clinic indicated

that a 10% decrease in oxidant levels was related to a 0.5% decrease in urgent visits. It should be noted that the oxidant readings in the data were sufficiently high to trigger six air pollution alerts in 1973 and one alert in 1974, and were among the highest ever recorded in the metropolitan Washington area.

4.4 Summary

From the data presented in Tables 4-2 and 4-3, it can be concluded that there are known human health effects (development of symptoms, decreased pulmonary function, and changes in blood biochemistry) resulting from exposure to ozone at levels equal to or greater than 0.2 ppm. Additional chamber studies are needed to evaluate the human health effects of ozone exposure at less than 0.2 ppm. These studies must include hypersusceptible subjects.

The studies reviewed previously for some affected counties indicate that Cook County is already in a range of concentration at which some adverse (mostly minor) health effects are likely to occur. This situation will continue whether or not the proposed regulation is adopted. There is no data indicating that a change in ozone concentration on the order of .004 ppm has any effect on health.

Any increase in a substance as inherently toxic as ozone is potentially capable of generating adverse health effects. However, given the projected increases (Table 2-1) in ozone concentration likely to result from the enforcement of R77-3, the current levels of ozone concentration, the accuracy of these data, and the paucity of reliable and sensitive dose-response information, it can be concluded that imposition of the proposed

regulation will lead to slight degradation of the environment but to no measurable adverse health effects.

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APPENDICES

Appendix A

Proposed Regulation No. R77-3

BEFORE THE POLLUTION CONTROL BOARD
OF THE STATE OF ILLINOIS

RECEIVED
JUN 08 1977
POLLUTION CONTROL BOARD

IN THE MATTER OF	)	
	)	
PROPOSED AMENDMENT TO RULE	)	
205(g)(1) OF THE ILLINOIS	)	R 77-3
POLLUTION CONTROL BOARD AIR	)	
POLLUTION CONTROL REGULATIONS	)	

AMENDED PETITION TO AMEND THE
AIR POLLUTION CONTROL REGULATIONS
CHAPTER 2, RULE 205(g)(1)

Now come The Sherwin-Williams Company, Monsanto Company, The B. F. Goodrich Company and Borg-Warner Corporation (hereinafter "the proponents"), by their attorneys, Clifton A. Lake and Dixie L. Laswell and, pursuant to Section 28 of the Illinois Environmental Protection Act, amend their petition for a change in Rule 205(g)(1) of Chapter 2 of the Illinois Pollution Control Board's Regulations as set forth below:

1. Rule 205(g)(1) is presently as follows:

(g) Waste Gas Disposal.

(1) Petroleum Refinery and Petrochemical Process Emissions. No person shall cause or allow the discharge of organic materials into the atmosphere from:

(A) any catalyst regenerator of a petroleum cracking system; or

(B) any petroleum fluid coker; or

(C) any other waste gas stream from any petroleum or petrochemical manufacturing process;

in excess of 100 ppm equivalent methane (molecular weight 16.0).

2. The amendment now proposed is as follows:

(g) Waste Gas Disposal.

(1) Petroleum Refinery and Petrochemical Manufacturing Emissions.

(A) Except as provided in 205(g)(1)(B), ~~No~~ no person shall cause or allow the discharge of organic materials into the atmosphere from:

~~(A)~~ (i) any catalyst regenerator of a petroleum cracking system; or

~~(B)~~ (ii) any petroleum fluid coker; or

~~(C)~~ (iii) any other waste gas stream from any petroleum or petrochemical manufacturing process;

in excess of 100 ppm equivalent methane (molecular weight 16.0).

(B) Exception. Existing sources subject to 205(g)(1)(A)(iii) may, alternatively, at their election, comply with the organic material emission limitations imposed by Rule 205(f) provided, however, that there shall be no increase in emissions from such sources above the level of emissions in existence on the effective date of this Rule 205(g)(1)(B).

(C) New sources. Sources subject to 205(g)(1)(A)(iii), construction of which commenced on or after January 1, 1977, may, at their election, comply with the following emission limitation:

(i) a maximum of eight pounds per hour of organic material; or

(ii) emission of organic material in excess of the limitation of subparagraph (i) is allowable if such emissions are controlled by air pollution control methods or equipment approved by the Agency capable of reducing by 85 percent or more the uncontrolled organic material that would otherwise be emitted to the atmosphere.*

3. The Sherwin-Williams Company, Monsanto Company, The B. F. Goodrich Company and Borg Warner Corporation, proponents of the proposed amendment, are major producers and users of a great variety of organic chemicals at various locations within the State of Illinois.

4. As set out above, the effect of the amended proposal would be the application of the organic material limitations imposed by Rule 205(f) to existing petroleum refinery and petrochemical manufacturing processes other than catalyst regenerators and petroleum fluid cokers at the election of the operator of the emission source. New petroleum refinery and petrochemical manufacturing processes other than catalyst regenerators and petroleum fluid cokers, at the election of the operator of the emission source, would meet organic material

*Strike outs denote omission of old language. Broken underlining denotes new language.

limitations of a maximum of eight pounds per hour or 85 percent control.

5. Proponents urge the amendment for the reason that most, if not all, of those industrial processes utilizing or producing organic materials, which might under some definitions of the term be deemed "petrochemicals," emit organic materials at a concentration in excess of the 100 ppm equivalent methane level permitted by Rule 205(g)(1). Emissions of organic materials from such processes therefore violate Rule 205(g)(1), notwithstanding that they may be entirely consistent with the mass emission limitations of Rule 205(f), or that through use of presently available and economically reasonable technology could easily comply with Rule 205(f). Proponents believe that control to a level of 100 ppm equivalent methane for such sources is not economically reasonable.

6. Proponents are informed and believe that while the existing emission limitation of Rule 205(g)(1) may be appropriate for certain major organic material emission sources located within petroleum refineries, such a limitation, when applied to processes which merely manufacture or use organic chemicals, imposes unnecessarily stringent and costly control requirements. Proponents believe that in lieu of the present concentration-based limitation of Rule 205(g)(1)(C) for such processes, the pound-per-hour or percent-control limitations of present Rule 205(f) are appropriate and economically reasonable.

7. Proponents do not believe that substitution of the organic material emission limitation of Rule 205(f) for that of Rule 205(g)(1)(C) as respects the processes referred to above will interfere with the attainment or maintenance of the national ambient air quality standards.

8. The purpose of the amendment is to make the limitations applicable to organic emissions from petrochemical manufacturing operations or processes consistent with those applicable to other emission sources of organic material.

WHEREFORE, proponents request that the Pollution Control Board authorize public hearings to consider the amended regulatory change proposed herein.

THE SHERWIN-WILLIAMS COMPANY,
MONSANTO COMPANY, THE B. F. GOODRICH
COMPANY and BORG-WARNER CORPORATION

BY _____
One of Their Attorneys

OF COUNSEL

Clifton A. Lake
Dixie L. Laswell
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(312) 372-5600

August 26, 1977

CERTIFICATE OF SERVICE

Dixie L. Laswell, one of the attorneys for the proponents herein, states that she caused a copy of the foregoing amended petition to be served on counsel for the Illinois Environmental Protection Agency by U.S. mail on August 26, 1977.

Dixie L. Laswell

Appendix B

Analysis of Hydrocarbon Emissions and Estimation of

"Out of Compliance" Sources Under Present and Proposed Regulations

Affected Population and Selection of Sample

The information on the number of plants and sources affected by R77-3 was obtained from IEPA and is summarized in Table B-1. However, in addition to this, it was necessary to have source by source information on actual and allowable emissions and the present hydrocarbon emission control practices to check the compliance status with the present and proposed regulations. Efforts were made to locate the above information from EPA emission inventory records on microfiche. The allowable emissions were not given and therefore these had to be calculated by using the flow rate, temperature conditions and hours of operation for each source. The actual formula used for calculating the allowable emissions in lbs./hr. under the existing regulations was:

$$\text{Hydrocarbon emissions } \left(\frac{\text{lbs.}}{\text{hr.}}\right) = \left(\text{flow rate } \frac{\text{ft.}^3}{\text{min.}}\right) \left(\frac{60 \text{ min.}}{1 \text{ hr.}}\right) \left(\frac{100 \text{ ppm}}{10^6}\right) \left(\frac{1}{\text{Sp. vol. of Hydrocarbon mixture}}\right)$$

Hours of operation were used to convert the above emissions into tons/year. Specific volume of the hydrocarbon mixture was calculated by using ideal gas law:

$$\text{Sp. Volume } \left(\frac{\text{ft.}^3}{\text{lb.}}\right) = \frac{RT}{P(M)}$$

where

$$R = \text{gas constant} = 0.7302 \frac{\text{atm. ft.}^3}{{}^{o}\text{R mole}}$$

Table B-1

Sources/Plants Affected by R77-3

County	Number of Plants	Number of Sources	Number of Sources Controlled
Cook	26	293	46
Will	5	64	1
Jo Daviess	1	5	0
Kane	3	10	7
Peoria	1	24	4
Marshall	1	62	8
Sangamon	1	18	8
LaSalle	2	13	8
St. Clair	3	54	13
Kankakee	2	2	0
Crawford	1	7	0
McHenry	1	37	17
Morgon	1	54	0
Grundy	2	18	0
DuPage	2	7	0
Madison	1	14	0
DeKalb	1	2	2
Rock Island	1	22	5
Douglas	1	11	0
Winnebago	1	68	0
Clark	1	22	1
Total	58	807	120

Source: Illinois EPA.

T = operating temperature in ^{o}R

P = pressure in atmospheres

M = Mol. Wt. of the hydrocarbon gases (assumed to be 80)

Out of a total of 807 sources subject to R77-3, the allowable emission patterns could be calculated for only 94 sources because of the limited information available through EPA emission inventory records. The unavailability of either the actual hydrocarbon emission data for the sources or the operating conditions like temperature and flow rate (required for calculating allowable emissions) precluded further analysis of the remainder of the sources. The information on sources for which emission data could be computed is given in Table B-2 along with their compliance status relative to the current and proposed regulations. Under the circumstances, it was decided to constitute a sample consisting of the above 94 sources. A comparison of the sample statistics with the population is given in Table B-3. As indicated in the Table, most of the counties represented in the sample included around 15 to 20 percent of the total number of sources in each county. In some extreme cases, there was complete representation primarily because of a small number of affected sources in those counties. Out of a total of 21 counties forming the population, only 9 could be included in the sample because of insufficient data. Overall, the sample constituted 11.6 percent of the affected sources and 29.3 percent of the affected plants in the population.

Table B-2

Hydrocarbon Emission Inventory Data for Sources Included in the Sample

County	Plant	Source Type	Existing Control Equipment	Number of Identical Sources	Hours of Operation (hrs./ days/ wks.)	Flow Rate (Actual Cubic Feet per Minute)	Gaseous Stream Temp. (°F)	Hydrocarbons: Uncontrolled Emission Rate (tons/yr.)	Hydrocarbons: Allowable Emissions[1] (tons/yr.)	Hydrocarbons: Control Efficiency	Hydrocarbons: Actual Emissions (tons/yr.)	Complies With: Present Regulation	Complies With: Proposed Regulation[2]
Cook	1	Mixing Tank	Condenser	1	6/1/26	924	70	0.34	0.09	99.9	0	yes	yes
		Resin Cooking Kettle	Scrubber & Condenser	2	12/5/52	5	110	13541.0	0.02	99.9	13.54	no	yes
		Sub-Total		3				13541.34	0.11		13.54		
	2	Reactor		1	18/5/52	1601	100	39.8	4.94	99.0	9.4	yes	yes
		Reducing Tank	Condenser	1	18/5/52	1	80	23.0	0.002	90.0	2.29	no	yes
		Reactor		1	18/5/52	1231	100	39.8	3.37	99.0	0.4	yes	yes
		Reducing Tank	Condenser	1	18/5/52	5	80	23.0	0.01	90.0	2.29	no	yes
		Reactor		1	18/5/52	1231	100	39.8	0.33	90.0	3.98	no	yes
		Reducing Tank	Condenser	1	18/5/52	4	100	23.4	0.01	90.0	2.34	no	yes
		Sub-Total		6				188.8	8.66		11.70		
	3	Reactor		2	6/5/52	3027	70	10.4	7.8		10.4	no	yes
	4	Chamber Incinerator	Afterburner & Scrubber	1	4/2/30	16200	300	0.16	1.68	99.0	.001	yes	yes
	5	Diethyl Phosphates		1	24/7/52	183	212	859.2	0.79		859.2	no	no
		Reactor	Condenser	1	24/7/52	1	85	387.0	0.004	99.0	0.63	no	yes
		Drying Still	Condenser	1	24/7/52	2	86	720.7	0.007	98.2	10.98	no	yes
		Drying Still	Condenser	1	24/7/52	3	100	3088.2	0.015	97.5	195.96	no	yes
		Still	Condenser	1	24/7/52	1	70	733.8	0.004	98.2	11.16	no	yes
	Sub-Total			5				5799.0	0.82		1077.93		
	6	Reactor	Scrubber	4	24/7/50	53084	100	4914.0	1046.64	97.0	147.32	yes	yes
		P.A. Flaker	Thermal Oxidizer	1	24/7/50	82000	110	84.0	397.32	99.0	0.84	yes	yes
	Sub-Total			5				4998.0	1443.96		148.16		
	7	Batch Mill		2	24/7/52	400	100	6.12	4.10		6.12	no	yes
		Mixer		2	24/7/52	400	100	4.36	4.10		4.36	no	yes
		Reactor	Scrubber	1	24/7/52	3977	100	0.437	20.40	99.6	0.0	yes	yes
		Reactor	Scrubber	1	24/7/52	3977	100	0.437	20.40	99.6	0.0	yes	yes
		Reactor	Scrubber & Condenser & Absorber	1	24/7/52	3977	100	47.2	20.40	99.6	0.17	yes	yes
		Recovery Tower	Scrubber	1	24/7/52	3977	100	16.6	20.40	99.6	3.04	yes	yes
		Reactor	Scrubber	1	24/7/52	3977	100	120.0	20.40	99.6	0.48	yes	yes
		Filter Tower		1	24/7/52	1560	180	6.86	6.99	90.0	6.86	yes	yes
		Reactor	Scrubber & Condenser & Absorber	1	24/7/52	3977	100	71.6	20.4	99.0	0.26	yes	yes
		Reactor	Scrubber & Condenser	1	24/7/52	3977	100	63.8	20.4	99.0	0.22	yes	yes
	Sub-Total			12				345.4	157.99		11.51		

Table B-2 (Continued)

Hydrocarbon Emission Inventory Data for Sources Included in the Sample

County	Plant	Source Type	Control Equipment	Number of Identical Sources	Hours of Operation (hrs./ days/ wks.)	Flow Rate (Actual Cubic Feet per Minute)	Gaseous Stream Temp. (°F)	Hydrocarbons: Uncontrolled Emission Rate (tons/yr.)	Hydrocarbons: Allowable Emissions[1] (tons/yr.)	Hydrocarbons: Control Efficiency	Hydrocarbons: Actual Emissions (tons/yr.)	Complies With: Present Regulation	Complies With: Proposed Regulation
	B	Unifier		1	24/7/52	17000	1000	3.06	33.7		3.06	yes	yes
		"		1	"	8800	800	3.49	20.09		3.49	yes	yes
		Phenal Unit	Thermal Oxidizer	1	"	3770	41	978.4	21.40	90.0	97.84	no	yes
		"		1	"	45	212	26.64	0.17		26.64	no	yes
		Crude Unit		1	"	71600	1000	27.52	160.65		27.52	yes	yes
		"		1	"	7060	800	3.06	16.16		3.06	yes	yes
		"		1	"	46300	1000	18.35	90.85		18.35	yes	yes
		"		1	"	41480	800	18.35	94.35		18.35	yes	yes
		"		1	"	73700	1300	530.71	120.21		530.71	no	no
		Platformer Units		1	"	48450	450	26.21	152.08		26.21	yes	yes
		"		1	"	15196	600	2.62	41.15		2.62	yes	yes
		"		1	"	48450	450	14.85	152.88		14.85	yes	yes
		"		1	"	8940	670	3.06	23.15		3.06	yes	yes
		Unifier		1	"	16800	725	1.75	41.06		1.75	yes	yes
		"		1	"	5750	700	1.31	14.41		1.31	yes	yes
		Isomex		1	"	9206	700	2.62	23.15		2.62	yes	yes
		Isomex		1	24/7/52	5100	700	2.62	12.67		2.62	yes	yes
		Isomex		1	24/7/52	17100	680	5.68	43.24		5.68	yes	yes
		Isomex		1	24/7/52	5450	500	2.18	16.16		2.18	yes	yes
		Alkylation Unit		1	24/7/52	19300	625	4.37	51.54		4.37	yes	yes
		Confidential		1	24/7/52	25000	1125	3.93	45.43		3.93	yes	yes
	Sub-Total			21				1681.0	1174.8		860.22		
County Total	6			55					2795.02		2040.44		
		Blending		1	7/2/20	15	150	0.74	0.003		0.74	no	yes
Peoria	1	Hydro-generator	Scrubber/ Condenser	1	24/7/52	60	90	31.9	0.31		11.09	no	yes
		Amine Extraction		1	24/7/26	8048	125	9.17	19.74		9.17	yes	yes
		Fatty Acid Splitting	Condenser	1	24/7/50	20	90	93.7	0.04	99.0	0.97	no	yes
		Fatty Acid Splitting	Condenser	1	24/7/50	10	90	29.4	0.04	99.0	0.29	no	yes
County Total	1			5				164.91	20.17		43.01		
Grundy	1	Reactor	Scrubber and Carbon Absorber	1	24/7/47	43000	100	4738.0	199.37	97.8	104.21	yes	yes
County Total	1			1				4738.0	199.37		104.21		
DuPage	1	Printing Ink Mfg.		1	8/5/50	7000	70	90.0	8.7		90.0	no	no
County Total	1			1				90.0	8.7		90.0		
Kankakee	1	Area 37 Process		1	24/7/4	103	85	18.88	0.04		18.88	no	yes
	2	Paint Manufact.		1	16/6/52	5000	70	15.72	15.48		15.72	no	yes
County Total	2			2				34.60	15.52		34.60		
Clark	1	Filter	After-burner	1	24/7/50	1	80	86.94	0.004	99.7	0.04	no	yes
		Unknown		1	24/7/50	280	220	15.12	1.11		15.12	no	yes
		Unknown		1	24/7/50	280	220	15.12	1.11		15.12	no	yes
County Total	3			3				117.18	2.26		31.28		

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Table B-2 (Continued)

Hydrocarbon Emission Inventory Data for Sources Included in the Sample

County	Plant	Source Type	Control Equipment	Number of Identical Sources	Hours of Operation (hrs./ days/ wks.)	Flow Rate (Actual Cubic Feet per Minute)	Gaseous Stream Temp. (°F)	Hydrocarbons: Uncontrolled Emission Rate (tons/yr.)	Hydrocarbons: Allowable Emissions[1] (tons/yr.)	Hydrocarbons: Control Efficiency	Hydrocarbons: Actual Emissions (tons/yr.)	Complies With: Present Regulation	Complies With: Proposed Regulation[2]
St. Clair	1	Benzene Recovery		5	24/7/52	1	70	4.35	0.02		4.35	no	yes
		Surge Tank		1	24/7/52	13	70	0.87	0.087		0.87	no	yes
		Alkylator		2	24/7/52	1	70	0.88	0.008		0.88	no	yes
		Quench Tank		1	8/5/52	341	212	0.10	0.34		0.10	yes	yes
		Jet E-121		1	8/5/52	5	370	8.74	0.017		8.74	no	yes
		Jet		1	8/5/52	219	370	0.44	0.74		0.44	yes	yes
County Total	1			11				15.38	1.21		15.38		
Will	1	Reactor		1	24/7/52	150	150	1554.0	183.12		1554.0	no	no
		Pethalic Anlydride Process		1	24/7/52	5	70	4.2	0.025		4.2	no	yes
		Methanol Condenser		1	24/5/52	1	165	0.62	0.003		0.62	no	yes
		Isopropyl Condenser		1	24/5/52	180	35	21.53	0.75		21.53	no	yes
		Distillation Column		1	24/5/52	1	80	7.49	0.003		7.49	no	yes
		Fractionation & Condenser		1	24/5/52	240	95	4.06	0.87		4.06	no	yes
		Reactor		1	24/5/52	500	212	7.49	1.53		7.49	no	yes
		Surge Tank		2	24/7/52	6	95	20.96	0.06		20.96	no	yes
		Reactor	Not Known	1	24/3/52	60	220	91.35	0.11	98.3	1.54	no	yes
		Reactor		1	24/7/52	100	150	0.44	0.7		0.44	yes	yes
County Total	1			11				1622.33	187.17		1622.33		
Jo Daviess	1	Ammonia Stream		2	24/5/50	37170	212	0.6	218.2		0.6	yes	yes
		Vent		1	24/7/52	360	50	0.44	2.01		0.44	yes	yes
		Stream Ammonia Manufact.		1	18/1/2	4145	450	152.06	0.06		152.06	no	no
		Stream		1	24/7/50	10500	660	0.42	25.96		0.42	yes	yes
County Total	1			5				153.52	246.23		153.52		

1. The allowable emissions are calculated based on 100 ppm limitation.
2. Compliance with the proposed regulations is checked based on 85 percent control or 8 lbs./hr. emission limitation.

Source: Illinois EPA Industrial Emission Inventory.

Table B-3

Comparison of Sample with the Population by County

County	Population Statistics		Sample Statistics			
			Plants		Sources	
	Number of Plants	Number of Sources	Number	% of Population	Number	% of Population
Cook*	26	293	8	30.8	55	18.8
Will*	5	64	1	20.0	11	17.2
Jo Daviess*	1	5	1	100.0	5	100.0
Kane	3	10	-	-	-	-
Peoria*	1	24	1	100.0	5	20.8
Marshall	1	62	-	-	-	-
Sangamon	1	18	-	-	-	-
LaSalle	2	13	-	-	-	-
St. Clair*	3	54	1	33.3	11	20.4
Kankakee*	2	2	2	100.0	2	100.0
Crawford	1	7	-	-	-	-
McHenry	1	37	-	-	-	-
Morgon	1	54	-	-	-	-
Grundy*	2	18	1	50.0	1	5.6
DuPage*	2	7	1	50.0	1	14.3
Madison	1	14	-	-	-	-
DeKalb	1	2	-	-	-	-
Rock Island	1	22	-	-	-	-
Douglas	1	11	-	-	-	-
Winnebago	1	68	-	-	-	-
Clark*	1	22	1	100.0	3	13.6
Total	58	807	17	29.3	94	11.6

*Counties selected for further analysis.

Sample Analysis

The sample information was analyzed to isolate the out of compliance sources under the current and/or proposed regulations and to calculate their allowable and actual emissions. The allowable emissions under current regulations were calculated based on 100 ppm methane equivalent limitation. For proposed regulations, which limits the hydrocarbon emissions to 8 lbs./hr. or 85 percent control, allowable emissions for out of compliance sources were based on 85 percent control since this will probably be the easier level of control to achieve for the plant and, therefore, will be preferred. This analysis was performed for each plant included in the sample and the results are presented in Table B-2.

Population Estimates

Two different approaches were used for arriving at population estimates.

Most Probable Case: The most probable case assumes that the emission pattern and the compliance status of all the sources in a plant can be represented by the results of the sources included in the sample from that plant. Further, the estimates for other affected sources in a county, not included in the sample, were based on the results of the sources included in the sample from that county. Similarly, the estimation of out of compliance sources and their hydrocarbon emissions for counties not included in the sample were based on the overall results of the out of compliance sources in the sample. This procedure was used for analyzing the results for out of compliance sources under the existing and the proposed regulations. The results of these analyses are presented in Tables B-4 and B-5. Validity of the results for Will county are

Table B-4

Population Estimates for "Out of Compliance" Sources Under Present Regulations - Most Probable Case

		Sample Statistics[1]				Population Estimates[2]				
		"Out of Compliance" Sources[4]				"Out of Compliance" Sources				
County	Plant	Number of Sources	Number	Allowable Emissions (tons/yr)	Actual Emissions (tons/yr)	Number of Sources	Number	Allowable Emissions (tons/yr)	Actual Emissions (tons/yr)	Reduction[3] (tons/yr.)
Cook	1	3	2	0.0	13.5	8	5	0.1	33.8	
	2	6	4	0.4	10.9	6	4	0.3	10.9	
	3	2	2	7.8	10.4	2	2	7.8	10.4	
	4	1	-	-	-	7	-	-	-	
	5	5	5	0.8	1077.9	5	5	0.8	1077.9	
	6	5	-	-	-	22	-	-	-	
	7	12	4	8.2	10.5	38	13	26.6	34.1	
	8	21	3	141.8	655.2	31	4	189.1	873.6	
Sub-total	8	55	20	159.0	1778.4	119	33	224.7	2040.7	
Other[5]	-	-	-	-	-	174	51	327.4	2973.6	
County Total	8	55	20	159.0	1778.4	293	84	552.1	5014.3	4462.2
Will	1	11	10	186.5	1621.9	27	25	192.2*	1735.1*	
Other[5]	-	-	-	-	-	37	34	12.8**	256.5**	
County Total	1	11	10	186.5	1621.9	64	59	205.0	1991.6	1768.6
Jo Daviess	1	5	1	0.1	152.1	5	1	0.1	152.1	
County Total	1	5	1	0.1	152.1	5	1	0.1	152.1	152.0
Peoria	1	5	4	0.4	33.8	24	19	2.0	160.6	
County Total	1	5	4	0.4	33.8	24	19	2.0	160.6	158.6
St. Clair	1	11	9	0.1	14.8	29	24	0.4	39.6	
Other[5]	-	-	-	-	-	25	21	0.3	34.6	
County Total	1	11	9	0.1	14.8	54	45	0.7	74.2	73.5
Kankakee	1	1	1	0.1	18.9	1	1	0.1	18.9	
	2	1	1	15.4	15.7	1	1	15.4	15.7	
County Total	2	2	2	15.5	34.6	2	2	15.5	34.6	19.1
Grundy	1	1	-	-	-	6	-	-	-	
Other[4]	-	-	-	-	-	12	-	-	-	
County Total	1	1	-	-	-	18	-	-	-	
Dupage	1	1	1	8.7	90.0	4	4	34.8	360.0	
Other[5]	-	-	-	-	-	3	3	26.1	270.0	
County Total	1	1	1	8.7	90.0	7	7	60.9	630.0	569.1
Clark	1	3	3	2.3	31.1	22	22	16.6	227.9	
County Total	1	3	3	2.3	31.1	22	22	16.6	227.9	211.3
Sub-Total	17	94	50	372.6	3756.7	489	239	882.9	8205.3	
Other Counties[6]	-	-	-	-	-	318	155	563.1	5373.2	4810.1
Total	17	94	50	372.6	3756.7	807	394	1406.0	13658.5	12252.5

* In the case of Will County, one of the "out of compliance" sources in the sample exhibited a comparatively large difference between the actual and allowable emissions (refer to Table B-2). Since this represents an abnormal case, the data from this source were not considered while extrapolating the sample results to a population estimate. The final population estimates for 25 "out of compliance" sources were therefore derived by estimating the emissions for 24 sources based on the balance 9 "out of compliance" sources in the sample, and by adding to this, the actual emission of the additional sample source not considered in extrapolation.

** These results were derived by linearly extrapolating the sample results. The results of source with abnormally large differences in actual and allowable emissions were not considered in deriving the population estimates.

1. These values are based on the data in Table B-2.
2. Population values are estimated by linearly extrapolating sample results.
3. These are the reductions in hydrocarbon emissions by county assuming complete compliance with the present regulations.
4. Out of compliance sources are evaluated based on the compliance status of sources included in Table B-2.
5. "Other" represent other affected sources in a county which could not be included in the sample because of insufficient data. The estimates for these sources are based on the analysis for sample sources in that county.
6. These are the counties which could not be represented in the sample because of insufficient data. The emission pattern of sources from these counties is calculated based on the analysis for the sample sources.

Note: The values are rounded off to one decimal place.

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Table B-5

Population Estimates for "Out of Compliance" Sources Under Proposed Regulations - Most Probable Case

		Sample Statistics[1]				Population Estimates[2]				
			"Out of Compliance" Sources[4]				"Out of Compliance" Sources			
County	Plant	Number of Sources	Number	Allowable Emissions[5] (tons/yr)	Actual Emissions (tons/yr)	Number of Sources	Number	Allowable Emissions[5] (tons/yr)	Actual Emissions (tons/yr)	Reduction[3] (tons/yr.)
Cook	1	3	-	-	-	8	-	-	-	
	2	6	-	-	-	6	-	-	-	
	3	2	-	-	-	2	-	-	-	
	4	1	-	-	-	7	-	-	-	
	5	5	1	130.4	869.2	5	1	130.4	869.2	
	6	5	-	-	-	22	-	-	-	
	7	12	-	-	-	38	-	-	-	
	8	21	1	79.6	530.7	31	1	79.6	530.7	
Sub-total	8	55	2	210.0	1399.9	119	2	210.0	1399.9	
Other[6]	-	-	-	-	-	174	3	315.0	2099.9	
County Total	8	55	2	210.0	1399.9	293	5	525.0	3499.8	2974.8
Will	1	11	1	233.1	1554.0	27	2	234.2*	1561.5*	
Other[6]		-	-	-	-	37	3	3.4*	22.6*	
County Total	1	11	1	233.1	1554.0	64	5	237.6	1584.1	1346.5
Jo Daviees	1	5	1	22.8	152.1	5	1	22.8	152.1	
County Total	1	5	1	22.8	152.1	5	1	22.8	152.1	129.3
Peoria	1	5	-	-	-	24	-	-	-	
County Total	1	5	-	-	-	24	-	-	-	
St. Clair	1	11	-	-	-	29	-	-	-	
Other[6]		-	-	-	-	25	-	-	-	
County Total	1	11	-	-	-	54	-	-	-	
Kankakee	1	1	1	2.8	18.9	1	1	2.8	18.9	
	2	1	-	-	-	1	-	-	-	
County Total		2	1	2.8	18.9	1	1	2.8	18.9	16.1
Grundy	1	1	-	-	-	6	-	-	-	
Other[6]	-	-	-	-	-	12	-	-	-	
County Total	1	1	-	-	-	18	-	-	-	
DuPage	1	1	1	13.5	90.0	4	4	54.0	360.0	
Other[6]	-	-	-	-	-	3	3	40.5	270.0	
County Total	1	1	1	13.5	90.0	7	7	94.5	630.0	535.5
Clark	1	3	-	-	-	22	-	-	-	
County Total	1	3	-	-	-	22	-	-	-	
Sub-Total	17	94	6	482.2	3214.9	489	19	882.7	5884.9	5002.2
Other Counties[7]	-	-	-	-	-	318	12	557.5	3716.8	3159.3
Total	17	94	6	482.2	3214.9	807	31	1440.2	9601.7	8161.5

* In the case of Will County, only one source in the sample was found to be out of compliance with the proposed regulations. This source exhibited abnormally large difference between the actual and allowable emissions and therefore could not be used as a representative case for deriving population estimates. Under the circumstances, the population estimates of actual emissions for "out of compliance" sources under the proposed regulations for Will County were based on the corresponding population estimates under the present regulations derived in Table B-4. The allowable emissions were then estimated based on 85 percent control.

1. These values are based on the data in Table B-2.
2. Population values are estimated by linearly extrapolating sampel results.
3. These are the reductions in hydrocarbon emissions by county assuming complete compliance with the proposed regulations.
4. Out of compliance sources are evaluated based on the compliance status of sources included in Table B-2.
5. Allowable emissions are based on 85 percent control of the actual emissions.
6. "Other" represents other affected sources in a county which could not be included in the sample because of insufficient data. The estimates for these sources are based on the analysis for sample sources in that county.
7. These are the counties which could not be represented in the sample because of insufficient data. The emission pattern of sources from these counties is calculated based on the analysis for the sample sources.

Note: The values are rounded off to one decimal place.

questionable for the following reasons:

- Will County has five plants which are affected by R77-3. Out of these, only one could be included in the sample because the required information for the other plants was not included in the state emission inventory.
- There are 27 affected sources in this one plant, out of these only 11 could be included in the sample because of insufficient data for the others.
- Based on sample results, under the existing regulations, 10 out of 11 sources were out of compliance and this, when translated to population statistics, resulted in 25 out of compliance sources of a total of 27 sources in that plant.
- The estimates for the other four plants in Will County (accounting for 37 sources) were based on the above sample results under the assumption that these will follow the same emission pattern as those of the one plant which comprised the sample in this case.

For the above reasons, the results for Will County have greater degree of uncertainty and should, therefore, be interpreted accordingly.

Worst Case: This alternative technique, like the most probable case, interprets the compliance status of the sources included in the sample based on the actual emission inventory data. However, the analysis for the other affected sources, not included in the sample, is carried out in a manner to maximize the increase in hydrocarbon emissions resulting by the passage of R77-3 over the levels estimated by assuming complete compliance with the existing regulations. This provides an extreme case

for review and is created by maximizing the reduction in existing hydrocarbon emissions under the present regulations and by minimizing the reduction in emissions under the proposed regulations. To achieve these conditions, all the non-sample sources are assumed to be out of compliance with the present regulations thereby maximizing the number of sources to be controlled and the associated reduction in hydrocarbon emissions. Under the proposed regulation these non-sample sources are considered to be in compliance with the regulation so as to minimize the number of out of compliance sources and the corresponding reduction in hydrocarbon emissions. The combined effects of the above will provide the maximum increase in the hydrocarbon emissions resulting from the passage of R77-3 over the levels estimated by assuming complete compliance with the present regulations. The results of these analyses are given in Tables B-6 and B-7.

Table B-8 gives a summary by county of the out of compliance sources under the present and proposed regulations for the most probable case. Table B-9 gives the same information for the worst case conditions. The information derived in this Appendix is used in Chapters 3 and 4 for calculating the benefits and the costs of adopting R77-3.

Table B-6

Population Estimates for "Out of Compliance" Sources under Present Regulations - Worst Case

		Sample Statistics[1]				Population Estimates[2]					
			"Out of Compliance" Sources[3]					"Out of Compliance" Sources			
County	Plant	Number of Sources	Number	Allowable Emissions (tons/yr)	Actual Emissions (tons/yr)	Number of Sources[4]	Sources Not Included in the Sample	Total[5]	Allowable Emissions (tons/yr)	Actual Emissions (tons/yr)	Reduction[6] (tons/yr)
Cook	1	3	2	0.0	13.5	8	5	7	0.1	47.53	
	2	6	4	0.4	10.9	6	0	4	0.4	10.90	
	3	2	2	7.8	10.4	2	0	2	7.8	10.4	
	4	5	5	0.8	1077.9	5	0	5	0.8	1077.93	
	5	12	4	0.2	10.5	38	28	30	61.5	78.5	
	6	21	3	161.8	655.2	31	10	13	614.4	2839.2	
	7	1	-	-	-	7	6	6			
	8	5	-	-	-	22	17	17	2212.0	13126.0	
	Other[7]	-	-	-	-	174	174	174			
County Total		55	20	159.0	1778.4	293	238	258	2897.0	17191.0	14294.0
Will	1	11	10	186.5	1621.9	27	16	26	192.5*	1742.6*	
	Other[7]	-	-	-	-	37	37	37	14.0**	279.1**	
County Total	1	11	10	186.5	1621.9	64	53	63	206.5	2021.7	1815.2
Jo Daviess	1	5	1	0.1	152.1	5	0	1	0.1	152.1	
County Total	1	5	1	0.1	152.1	5	0	1	0.1	152.1	152.0
Grundy	1	1	-	-	-	6	5	5	48.7	335.7	
	Other[7]	-	-	-	-	12	12	12	116.9	805.6	
County Total	1	1	-	-	-	18	17	17	165.6	1141.3	9757.0
Peoria	1	5	4	0.43	33.8	24	19	23	2.5	194	
County Total	1	5	4	0.43	33.8	24	19	23	2.5	194	191.5
St. Clair	1	11	9	0.13	14.84	29	18	27	0.4	44.5	
	Other[7]	-	-	-	-	25	25	25	0.37	41.2	
County Total	1	11	9	0.13	14.84	54	43	52	0.77	85.7	84.9
Kankakee	1	1	1	0.1	18.9	1	0	1	0.04	18.88	
	2	1	1	15.4	15.7	1	0	1	15.48	15.72	
County Total	2	2	2	15.5	34.6	2	0	2	15.52	34.60	19.1
DuPage	1	1	1	6.7	90.0	4	3	4	34.8	360.0	
	Other[7]	-	-	-	-	3	3	3	26.1	270.0	
County Total	1	1	1	6.7	90.0	7	6	7	60.9	630.0	569.1
Clark	1	3	3	2.3	31.1	22	19	22	16.6	227.9	
County Total	1	3	3	2.3	31.1	22	19	22	16.6	227.9	211.3
Subtotal	17	94	50	372.6	3756.6	488	395	445	3365.5	21678.3	18312.8
Other Counties[8]	-	-	-	-	-	319	319	319	2412.6	15540.2	13127.6
Total	17	94	50	372.6	3756.6	807	714	764	5778.1	37218.5	31440.4

* In the case of Will County, one of the "out of compliance" sources in the sample exhibited a comparatively large difference between the actual and allowable emissions (refer to Table B-2). Since this represents an abnormal case, the data from this source were not considered while extrapolating the sample results to a population estimate. The final population estimates for 26 "out of compliance" sources were therefore derived by estimating the emissions for 25 sources based on the balance 9 "out of compliance" sources in the sample, and by adding to this, the actual emission of the additional sample source not considered in extrapolation.

** These results were derived by linearly extrapolating the sample results. The results of source with abnormally large differences in actual and allowable emissions were not considered in deriving the population estimates.

[1] These values are based on the data in Table B-2.

[2] Population values are based on the worst case conditions as explained in the text.

[3] These are the reductions in hydrocarbon emissions by county assuming complete compliance with the present regulations.

[4] "Out of compliance" sources are evaluated based on the compliance status of sources included in Table B-2.

[5] These are based on the data provided by IEPA.

[6] The total out of compliance sources are found by adding the "out of compliance" sources in the sample, and sources not included in the sample, since under the worst case, all the non-sample sources are assumed to be out of compliance with the present regulations.

[7] "Other," these represent the other affected sources in a county which could not be included in the sample because of insufficient data. Based on the worst case criterion, these sources are assumed to be out of compliance with the present regulations.

[8] These are the counties which could not be represented in the sample because of insufficient data. Based on the worst case criterion, sources in these counties are assumed to be out of compliance with the present regulations.

Table B-7

Population Estimates for "Out of Compliance" Sources under the Proposed Regulations - Worst Case

		Sample Statistics[1]				Population Estimates[2]					
			"Out of Compliance" Sources[3]					"Out of Compliance" Sources[4]			
County	Plant	Number of Sources	Number	Allowable Emissions[5] (tons/yr)	Actual Emissions (tons/yr)	Number of Sources[6]	Sources Not Included in the Sample	Total[7]	Allowable Emissions[5] (tons/yr)	Actual Emissions (tons/yr)	Reduction[8] (tons/yr)
Cook	1	3	-	-	-	8	5	-	-	-	
	2	6	-	-	-	6	0	-	-	-	
	3	2	-	-	-	2	0	-	-	-	
	4	1	-	-	-	7	6	-	-	-	
	5	5	1	130.4	869.2	5	0	1	130.4	869.2	
	6	5	-	-	-	22	17	-	-	-	
	7	12	-	-	-	38	26	-	-	-	
	8	21	1	79.6	530.7	31	10	1	79.6	530.7	
	Other[9]	-	-	-	-	174	174	-	-	-	
County Total		55	2	210.0	1399.9	293	238	2	210.0	1399.9	1189.9
Will	1	11	1	233.1	1554.0	27	16	1	233.1	1554.0	
	Other[9]	-	-	-	-	37	37	-	-	-	
County Total	1	11	1	233.1	1554.0	64	53	1	233.1	1554.0	1320.9
Jo Daviess	1	5	1	22.8	152.1	5	0	1	22.8	152.1	
County Total	1	5	1	22.8	152.1	5	0	1	22.8	152.1	129.3
Peoria	1	5	-	-	-	24	19	-	-	-	
County Total	1	5	-	-	-	24	19	-	-	-	-
St. Clair	1	11	-	-	-	29	18	-	-	-	
	-	-	-	-	-	25	25	-	-	-	
County Total	1	11	-	-	-	54	43	-	-	-	-
Kankakee	1	1	1	2.8	18.9	1	0	1	2.8	18.9	
	2	1	-	-	-	1	0	-	-	-	
County Total	2	2	1	2.8	18.9	2	0	1	2.8	18.9	16.1
Grundy	1	1	-	-	-	6	5	-	-	-	
	Other[9]	-	-	-	-	12	12	-	-	-	
County Total	1	1	-	-	-	18	17	-	-	-	-
DuPage	1	1	1	13.5	90.0	4	3	1	13.5	90.0	
	Other[9]	-	-	-	-	3	3	-	-	-	
County Total	1	1	1	13.5	90.0	7	6	1	13.5	90.0	76.5
Clark	1	3	-	-	-	22	19	-	-	-	
County Total	1	3	-	-	-	22	19	-	-	-	-
Subtotal Other Counties[10]	17	94	6	482.2	3214.9	499	395	6	482.2	3214.9	2732.7
	-	-	-	-	-	318	318	-	-	-	-
Total	17	94	6	482.2	3214.9	807	713	6	482.2	3214.9	2732.7

[1] These values are based on the data in Table B-2.

[2] Population values are based on the worst case conditions as explained in the text.

[3] These are the reductions in hydrocarbon emissions by county assuming complete compliance with the proposed regulations.

[4] "Out of compliance" sources are evaluated based on the compliance status of sources included in Table B-2.

[5] Allowable emissions are based on 85 percent control of the actual emission.

[6] These are based on the data provided by IEPA.

[7] This value is the same as the number of "out of compliance" sources in the sample since under the worst case, all the non-sample sources are considered to be in compliance with the proposed regulation.

[8] "Other," these represent the other affected sources in a county which could not be included in the sample because of insufficient data. Based on the worst case criterion, these sources are assumed to be in compliance with the proposed regulations.

[9] These are the counties which could not be represented in the sample because of insufficient data. Based on the worst case condition, sources in these counties are assumed to be in compliance with the proposed regulations.

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Table B-8

Summary of "Out of Compliance" Sources under Most Probable Case

County	Number of Affected Sources	"Out of Compliance" Sources - Present Regulations			"Out of Compliance" Sources - Proposed Regulations		
		Number	Allowable Emissions (tons/yr)	Actual Emissions (tons/yr)	Number	Allowable Emissions (tons/yr)	Actual Emissions (tons/yr)
Cook	293	84	552.1	5014.3	5	525.0	3499.8
Will	64	59	205.0	1991.6	5	237.6	1584.1
Jo Daviess	5	1	0.1	152.1	1	22.8	152.1
Peoria	24	19	2.0	160.6	-	-	-
St. Clair	54	45	0.7	74.2	-	-	-
Kankakee	2	2	15.5	34.6	1	2.8	18.9
Grundy	18	-	-	-	-	-	-
DuPage	7	7	60.9	630.0	7	94.5	630.0
Clark	22	22	16.6	227.9	-	-	-
Others	318	155	553.1	5373.2	12	557.5	3716.8
Total	807	394	1406.0	13658.4	31	1440.2	9601.7

NOTE: These figures are based on the information in Tables B-4 and B-5.

Table B-9

Summary of "Out of Compliance" Sources under Worst Conditions

County	Number of Affected Sources	"Out of Compliance" Sources - Present Regulations			"Out of Compliance" Sources - Proposed Regulations		
		Number	Allowable Emissions (tons/yr)	Actual Emissions (tons/yr)	Number	Allowable Emissions (tons/yr)	Actual Emissions (tons/yr)
Cook	293	258	2897.0	17191.0	2	210.0	1399.9
Will	64	63	206.5	2021.7	1	233.1	1554.0
Jo Daviess	5	1	0.1	152.1	1	22.8	152.1
Peoria	24	23	2.5	194.0	-	-	-
St. Clair	54	52	0.8	85.7	-	-	-
Kankakee	2	2	15.5	34.6	1	2.8	18.9
Grundy	18	17	165.6	1141.3	-	-	-
DuPage	7	7	60.9	630.0	1	13.5	90.0
Clark	22	22	16.6	227.9	-	-	-
Others	336	336	2412.6	15540.2	-	-	-
Total	807	764	5778.1	37218.5	6	482.2	3214.9

NOTE: These figures are based on the data in Tables B-6 and B-7.

Appendix C

A Review of Hydrocarbon Control Technology

Hydrocarbon emissions can be reduced by add-on control devices. The efficiency of control and the relative effectiveness of the control devices will depend on the concentration and type of hydrocarbons, operating conditions, source of emission and other process related factors.

Carbon Adsorption

In this process, the gas stream from the process, containing hydrocarbons, is allowed to pass through the carbon bed where hydrocarbons are extracted from the gas stream. The basic principle is that the non-polar molecules (e.g. hydrocarbons) are adsorbed by non-polar adsorbent while the polar molecules escape through the bed. The surface area of the activated carbon is the primary variable in performance. The larger the available area, the larger the adsorption capacity of the carbon.

To remove adsorbed vapor and reuse the carbon, regeneration is necessary. Regeneration is the removal of adsorbed organics from the carbon and is accomplished by bringing the bed to near equilibrium at a higher temperature. Regeneration is typically about 50 percent complete for each cycle under proper operation. If a condensable regenerant like steam is used for regeneration, the steam and hydrocarbon vapor mixture can be routed to a condenser after which they can usually be separated by gravity or distillation. If a non-condensible gas is used for regeneration, the hydrocarbons can be removed directly by condensation.

The range of concentrations for which carbon adsorption is applicable is limited. Low concentrations can result in increased operating costs.

High concentrations can cause problem because of exothermic nature of the process. Typically 200 to 300 Btu of heat is generated per lb. of solvent adsorbed. Therefore, high concentrations can overheat the bed resulting in poor adsorption.

The control efficiency of carbon adsorption process is usually around 90 percent.

Condensation

The underlying principle behind condensation process is that any component(s) of a vapor mixture can be condensed if brought to equilibrium at a low enough temperature.

The primary process variables to be adjusted are the temperature and the pressure. Once one is fixed, the other can be evaluated by equilibrium considerations. For instance, if there is only one hydrocarbon component to be separated from the gas stream, the condensation will start when a temperature is reached such that the vapor pressure of the hydrocarbon component is equal to its partial pressure. As the vapor is cooled further, condensation continues such that the partial pressure stays equal to the vapor pressure. If there are more than one hydrocarbon components present in the gas stream, the condensation temperature can be found by using the vapor-liquid equilibrium constants for the hydrocarbon components and the total pressure.

In cases where the hydrocarbon vapor concentration is high, for example, from the desorption cycle of a carbon adsorber, condensation is relatively easy. However, for sources where concentrations are low, condensation is very difficult.

Absorption

Absorption involves dissolving a soluble hydrocarbon component in a relatively non-volatile liquid. Common absorbents for organic

vapors are water, non-volatile organics, and aqueous solutions. Actual selection depends on the particular hydrocarbons involved. Absorption is increased by lower temperatures, higher solubility of the hydrocarbons, higher concentrations of the hydrocarbons, higher liquid to gas ratios, and greater contacting surface. These absorbed hydrocarbons are generally recovered by heating to lower the solubility, or by distillation.

The effectiveness of the absorption-regeneration approach for organic solvents is severely limited by the low concentrations and consequent low solubilities of most hydrocarbons in the absorbent. Exceptions are alcohols, ketones, amines, glycols, aldehydes, phenol and organic acids.

Incineration

Incineration destroys hydrocarbon emissions by oxidizing them to carbon dioxide and water vapors. Oxidation proceeds more rapidly at higher temperatures and higher hydrocarbon content.

Incineration can be carried out through the use of existing process heaters or by employing the use of add-on incinerators. The use of existing process heaters provides for the possibility of hydrocarbon emission control at small capital cost and little or no fuel cost. There are, however, some severe limitations to its application in the form of heater operation, temperature and residence time in the heater and fuel rate to the burner.

In the case of add-on incinerators, the control process can be carried out non-catalytically or by using a catalyst to speed up the conversion. In non-catalytic process, a portion of the gas stream is passed through the burner(s) in which auxiliary fuel is fired. Gases exiting the burner(s) in excess of 2000°F are blended with the bypassed

gases and held at that temperature until the reaction is complete. The equilibrium temperature of mixed gases is critical to effective combustion. In catalytic incineration, use of a catalyst enables satisfactory oxidation rates at considerably low temperatures.

The incineration fuel requirements are determined by the concentration of the hydrocarbons, the waste stream temperature, oxygen level and the incineration temperature required. Heat recovery offers a way to reduce the energy consumption of incinerators. "Primary" heat recovery utilizes the hot cleaned gases exiting the incinerator to preheat the cooler incoming gases. "Secondary" heat recovery utilizes the incinerator exhaust from the primary heat recovery stage (or from the incinerator directly if there is no primary heat recovery) to replace energy usage elsewhere in the plant.

The incineration process can achieve 95+ percent removal of the hydrocarbons present.

Appendix D

Estimation of Capital and Operating Costs for the Control Technology Options

The procedure for calculating the costs was based on the guidelines provided by Manufacturing Chemists Association in their report on "Cost of Hydrocarbon Emissions Control to the U.S. Chemical Industry (SIC 28)", 1977.[16] Table D-1 gives a summary of the cost components considered and the cost factors used for various control technologies. The explanation for some of the items in the Table is given below.

Cost of Equipment

F.O.B. cost of equipment is based on the cost curves given in the above referenced report by Manufacturing Chemists Association. The flow rates required for reading the cost curves are taken from Table 3-1 for each of the Source Categories. In the case of condensers, the cost curves are given in terms of the heat transfer surface area and the refrigeration capacity required to condense the hydrocarbons. These variables were therefore evaluated for each source category before reading the F.O.B. costs from the curves.

Project Cost Factor

This factor accounts for the additional project cost components including installation, instrumentation, engineering and construction expenses, electrical connections and contingencies.

Additional Cost Factor

This figure represents costs other than those included under the project cost factor such as expenses for additional fan or additional duct work.

Table D-1

Cost Calculation Worksheet for Hydrocarbon Emission Control Technologies

	Thermal Incineration	Catalytic Incineration	Carbon Adsorber with Recovery	Condenser	Absorber
Project Cost					
(1) Cost of Equipment					
(2) Project Cost Factor	2.8	2.8	2.7	3.7	3.6
(3) Additional Cost Factor	0.2	0.2	0.2	0.2	0.2
(4) Total Project Cost ((2+3) x 1)					
Energy Requirement					
(5) Fuel (x 10^6 BTU)					
(6) Power (KW Factor)	3.0	3.8	3.0	0.9KW/ton	5.4
(7) Steam (lbs./lb. hydrocarbon)			15		
Annualized Operating Cost					
(8) Depreciation (10 percent of (4))					
(9) Taxes, Insurance & Interest 8% of (4)					
(10) Maintenance and Repair	3%	9%	6%	4%	6%
(11) Operating Labor (No. of Operators x $20,000)	$5,000	$5,000	$5,000	$5,000	$5,000
(12) Fuel Cost ($2.50/$10^6$ BTU x (5))					
(13) Power Cost ($0.03 x KWH)					
(14) Steam Cost ($1.00 x (7))					
TOTAL OPERATING COST					
Less:					
(15) Value of Recovered Hydrocarbons					
NET OPERATING COST					

Note: Explanation for various cost components is given in the Appendix D text.

Source: "Costs of Hydrocarbon Emissions Control to the U.S. Chemical Industry", Manufacturing Chemists Association, 1976.

Fuel Requirements

Incineration is the only control technology considered which requires direct use of a fuel to oxidize the hydrocarbons. The fuel requirement is dependent on the flow rate, inlet temperature, hours of operation and the heating value of the hydrocarbons. To reduce the fuel costs, it was assumed that heat exchangers would be installed downstream of the retention chamber in the unit to recover some of the heat from the exhaust gases by preheating the inlet contaminated stream. For purposes of this study, a heat exchanger was assumed to have 50 percent efficiency. The fuel requirements with heat exchange are calculated from the following equations:

Thermal Incineration

$$\text{BTU/year} = 1.26V\left(\frac{(1300-T)}{2} - T\right) - 60HVC\ S$$

where

V = volumetric flow rate in acfm (actual cubic feet per minute).

T = inlet temperature in ^{o}F

S = hours of operation in a year

H = heat value of the hydrocarbon stream (19,000 BTU/lbs. hydrocarbons)

C = concentration of hydrocarbons in the stream (lbs/ft^3)

Catalytic Incineration

$$\text{BTU/year} = \left[1.21V \left(\frac{(700-T)}{2} - T \right) - 60HVC \right] S$$

where various symbols have the same meaning as in the case of thermal incineration.

Power Requirement

The total power requirement is estimated by the following relationship.

$$\text{KWH} = \frac{\text{KW}}{1000 \text{ cfm}} \times \text{cfm} \times \text{hours of operation}$$

The KW factors are given in Table D-1. In the case of condensers, the value is based on the number of KW's required per ton of refrigeration rather than the volumetric flow rate.

Steam Requirement

Steam is required for carbon adsorption process during the recovery stage. It is calculated as

$$\text{Steam} = \frac{\text{lbs. steam}}{\text{lb. hydrocarbon}} \times \frac{\text{lbs. hydrocarbon}}{\text{year}}$$

The capital and operating costs were caluclated for the control technologies for each of the following source categories:

- Reactors
- Stills/Reducing tanks
- Recovery Units

- Mixing Units
- Miscellaneous

The required average operating data were taken from Table 3-1.

Value of Recovered Material

The value of recovered material was based on 90 percent control efficiency and an average hydrocarbon price of $0.15 per lb. The average hydrocarbon price was estimated from the hydrocarbon prices given in the Chemical Marketing Reporter (May 1978).

Selection of Control Equipment

Since no information was available on the process details and the manufacturing characteristics of the sources under consideration, it was not possible to segment the sources according to technology and product characteristics and thus suggest an optimum cost-effective control device for each segment. Under the circumstances, it was decided to review the available IEPA emission inventory data and analyze the existing use of control technologies by source category. These results are presented in Table D-2. As is evident, on the overall basis, condensers are more commonly used as compared to other control technologies, and the incineration process is least used, one reason for this is the high capital investment required. The results of Table D-2 are used in estimating the distribution of "out of compliance" sources and the corresponding requirement of control technologies for compliance with the present regulations. The out of compliance sources are those which need control under the present regulations but which are in compliance with the proposed regulations. Based on the analysis presented in Appendix B, their total number is estimated at 363. This information is ultimately

Table D-2

Sample Analysis on the Existing Use of Control Technologies by Source Category

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Condensers		Carbon Absorbers		Absorption		Thermal Incineration		Catalytic Incineration		Total	
Source Category	Number	Percentage[1]	Number	Percentage[1]	Number	Percentage[1]	Number	Percentage[1]	Number	Percentage[1]	Number	Percentage[2]
Reactor	19	52.8	7	19.4	9	25.0	1	2.8	-	-	36	57.1
Reducing Tanks/Stills	12	80.0	-	-	2	13.3	1	6.7	-	-	15	23.8
Recovery Units	2	33.3	-	-	2	33.3	1	16.7	1	16.7	6	9.5
Mixing/Blending	1	33.3	2	66.7	-	-	-	-	-	-	3	4.8
Misc.	-	-	-	-	1	33.4	1	33.3	1	33.3	3	4.8
Total	34	54.0	9	14.3	14	22.2	4	6.3	2	3.2	63	100.0

1. Represents the number of units of control equipment used in each source category as a percentage of total sources included in that source category for analysis.

2. Represents the no. of sources in each source category as a percentage of total number of sources included in the analysis.

Note: Information on the sample sources and their control practices was taken from the source inventory data provided by IEPA.

used to calculate the additional control costs to be incurred by the industries if R77-3 is not passed. The final distribution of the out of compliance sources by source category and the corresponding units of control devices is summarized in Table D-3. The capital and operating costs associated with all the control technologies were calculated for each source category individually based on the procedure outlined in Table D-1. These costs were used in coordination with the information developed in Table D-3 to calculate the total control costs. These costs are summarized in Section 3.

Table D-3

Number of Units and Distribution of Control Equipment by Source-Category for Compliance with the Existing Regulations[1]

Source Category	"Out of Compliance" Sources[2]	Number of Units of Control Equipment[3]				
		Condenser	Carbon Absorber	Absorbers	Thermal Incineration	Catalytic Incineration
Reactor	207	109	40	52	6	-
Reducing Tanks/Stills	87	70	-	11	6	-
Recovery Units	35	12	-	11	6	6
Mixing/Blending	17	6	11	-	-	-
Miscellaneous	17	-	-	6	6	5
TOTAL	363	197	51	80	24	11

Note:
1. Additional control requirement is considered for only those sources which comply with the proposed regulations but which are out of compliance with the present regulations.
2. "Out of Compliance" sources are those which need additional control equipment under the existing regulations and are in compliance with the proposed regulations. The calculations are based on the relative distribution of various source categories in the sample as given in column (12) of Table D-2.
3. The requirements for various control devices are based on the results of columns (2), (4), (6), (8) and (10) in Table D-2.

Appendix E

Effects of the Present and Proposed Regulations on Ozone Levels

Ambient levels of ozone reflect a complex interaction of locally emitted organic pollutants and oxides of nitrogen with transported ozone and precursors within the framework provided by prevailing meteorological conditions. The role of ambient oxides of nitrogen (NO_x) provide the basic means for ozone formation while the presence of appreciable amounts of hydrocarbons shifts the equilibrium between ozone and NO_x so that higher concentrations of ozone prevail.[1]

The effect of both the present and the proposed regulations is to reduce the existing hydrocarbon emissions. Based on the role of hydrocarbons in ozone formation, compliance with either of the regulations will reduce the ozone levels also. However, the reduction in hydrocarbon emissions and the corresponding reduction in ozone levels will be greater under the present regulations because of lower allowable emissions. The effects of replacing present with the proposed regulation are, therefore, determined in terms of the net increase in hydrocarbon emissions estimated by the difference of reductions achieved in existing emissions under the two regulations. These effects are then translated into an increase in ozone levels.

Estimation of the Change in Hydrocarbon Emissions

Reduction in the existing hydrocarbon emissions under the present and proposed regulations have been analysed in Appendix B based on the most probable and the worst case. As explained in Appendix B and Section 3,

the "most probable" case assumes the sample to be a complete representative of the whole population and the overall results are interpreted accordingly. The "worst case" interprets the results of non-sample sources in a manner which will maximize the increase in hydrocarbon emissions associated with the change in regulations and thus provide an extreme case for review. Table E-1 and Table E-2 give a county by county summary of the increase in hydrocarbon emissions for nine sample counties based on the most probable and the worst case and their comparison with the total hydrocarbon emissions in each county. The total emissions by county were provided by IEPA and are based on 1975 figures. The emission levels from point sources were updated based on the State Emission Inventory for 1978. Emissions from the area sources and the mobile sources had not yet been updated by IEPA and therefore 1975 figures were used. Also on the recommendation of IEPA, the hydrocarbon emissions resulting from solvent evaporation were not considered because there is considerable uncertainty with the presently available figure. This means that the total hydrocarbons may be significantly higher than those listed in Tables E-1 and E-2. Therefore, the calculated percent increase in ozone levels is higher than the values expected if actual total hydrocarbons were known.

Effect of Changes in Hydrocarbon Emissions on Ozone Levels

The effect of increase in hydrocarbon emissions on the ozone levels in the affected counties was found by using an Empirical Kinetic Modeling Approach (EKMA). EKMA utilizes a set of ozone isopleths which depict maximum afternoon concentrations of ozone downwind from a city as a

Table E-1

Increase in Hydrocarbon Emissions Associated with R77-3 - Most Probable Case[1]

County	(1) Reduction in Existing Hydrocarbon Emissions (tons/yr.)[2] Present Regulations[3]	(2) Reduction in Existing Hydrocarbon Emissions (tons/yr.)[2] Proposed Regulations[4]	(3) Net Increase in Emissions[5] (tons/yr.) (1) - (2)	(4) Total Hydrocarbon Emissions[6] (tons/yr.)	(5) Increase as a Percentage of Total (3) x 100/(4)
Cook	4462.2	2974.8	1487.4	411817	0.36
Will	1786.6	1346.5	440.1	31022	1.42
Jo Daviess	152.0	129.3	22.7	2013	1.13
Peoria	158.6	-	158.6	11543	1.37
St. Clair	73.5	-	73.5	24410	0.3
Kankakee	19.1	16.1	3.0	7422	0.04
Grundy	-	-	-	5788	-
Dupage	569.1	535.5	33.6	38187	0.09
Clark	211.3	-	211.3	2030	10.41
Others	4820.1[7]	3159.3[7]	1660.8	408800	0.41
Total	12252.5	8161.5	4091.0	943032	0.43

1. Most probable case assumes the sample to be representative of the population and the final results are estimated accordingly. The increase in hydrocarbon emissions is over the levels estimated by assuming complete compliance with the existing regulations.
2. The existing hydrocarbon emissions are higher than the anticipated levels under either of the regulations. Therefore the effect of enforcing the present or the proposed regulations is to reduce the existing hydrocarbon levels. However, the reduction in hydrocarbon levels assoicated with the present regulations is more because of lower allowable emissions. The passage of R77-3 will therefore result in a net increase over the anticipated hydrocarbon emission levels under the present regulation.
3. These figures are based on the results of Table B-4 in Appendix B.
4. These figures are based on the results of Table B-5 in Appendix B.
5. This is the net increase in hydrocarbon emissions associated with R77-3 over the anticipated levels assuming complete compliance with the present regulation.
6. Total hydrocarbon emissions were based on the IEPA State Emission Inventory Information. Emissions due to solvent evaporation are not included since there is considerable uncertainty associated with the presently available figures.
7. Results for the non sample counties were estimated based on the estimates for the sample counties.

Table E-2

Increase in Hydrocarbon Emissions Associated with R77-3 - Worst Case[1]

County	(1) Reduction in Existing Hydrocarbon Emissions (tons/yr.)[2] Present Regulations[3]	(2) Reduction in Existing Hydrocarbon Emissions (tons/yr.)[2] Proposed Regulations[4]	(3) Net Increase in Emissions[5] (tons/yr.) (1) - (2)	(4) Total Hydrocarbon Emissions[6] (tons/yr.)	(5) Increase as a Percentage of Total (3) x 100/(4)
Cook	14294.0	1189.9	13104.1	411817	3.18
Will	1815.2	1320.9	494.3	31022	1.6
Jo Daviess	152.0	129.3	22.7	2013	1.13
Peoria	191.5	-	191.5	11543	1.66
St. Clair	84.9	-	84.9	24410	0.35
Kankakee	19.1	16.1	3.0	7422	0.04
Grundy	975.7	-	975.7	5788	16.86
Dupage	569.1	76.5	492.6	38187	1.29
Clark	211.3	-	211.3	2030	10.41
Others	13127.6	-	13127.6	408800	3.2
Total	31440.4	2732.7	28707.7	943032	3.04

1. The worst case provides a case of maximum increase in hydrocarbon emissions assoicated with R77-3 over the anticipated levels assuming complete compliance with the present regulation.
2. The existing hydrocarbon emissions are higher than the anticipated levels under either of the regulations. Therefore the effect of enforcing the present or the proposed regulations is to reduce the existing hydrocarbon levels. However, the reduction in hydrocarbon levels associated with the present regulations is more because of lower allowable emissions. The passage of R77-3 will therefore result in a net increase over the anticipated hydrocarbon emission levels under the present regulation.
3. These figures are based on the results of the analysis in Table B-6 in Appendix B.
4. These figures are based on the results of the analysis in Table B-7 in Appendix B.
5. This is the net increase in hydrocarbon emissions associated with R77-3 over the anticipated levels assuming complete compliance with the present regulation.
6. Total emissions were based on the IEPA State Emission Inventory Information. Emissions due to solvent evaporation are not included as there is considerable uncertainty associated with the presently available figure.

function of initial (i.e., morning) concentrations of non-methane hydrocarbons (NMHC) and nitric oxides (NO_x), meteorological conditions, reactivity of the precursor mix and concentrations of ozone and precursors transported from upwind areas. There are two versions of EKMA. The first involves the use of city-specific ozone isopleths derived by considering the above mentioned variables. The second utilizes a standard set of ozone isopleths in which fixed assumptions have been made about sunlight intensity, atmospheric dilution rate, reactivity and diurnal emission patterns. Since estimates about the relative changes in concentrations of ozone and hydrocarbons are comparatively less sensitive to the above assumptions, the standard isopleths have been used for the purposes of this study. The advantages of using standard isopleths of EKMA are that less input information is involved and no actual computer modeling is done. Figure E-1 shows a standard EKMA isopleth which has been used to estimate the effects of increase in hydrocarbon emissions on the ozone levels.[1]

Input data for EKMA includes the design value of ozone and the $NMHC/NO_x$ ratio. The design value is the second highest hourly ozone concentration observed during the base period and should normally be adjusted to discount for the effect of transported ozone before being used in EKMA. However, the effect of transported ozone was ignored since these values were not known for the affected counties. Also, after considering the additivity factors, the net effect of transported ozone on the second highest ozone levels was not expected to be large enough to cause any significant error in calculating the relative changes

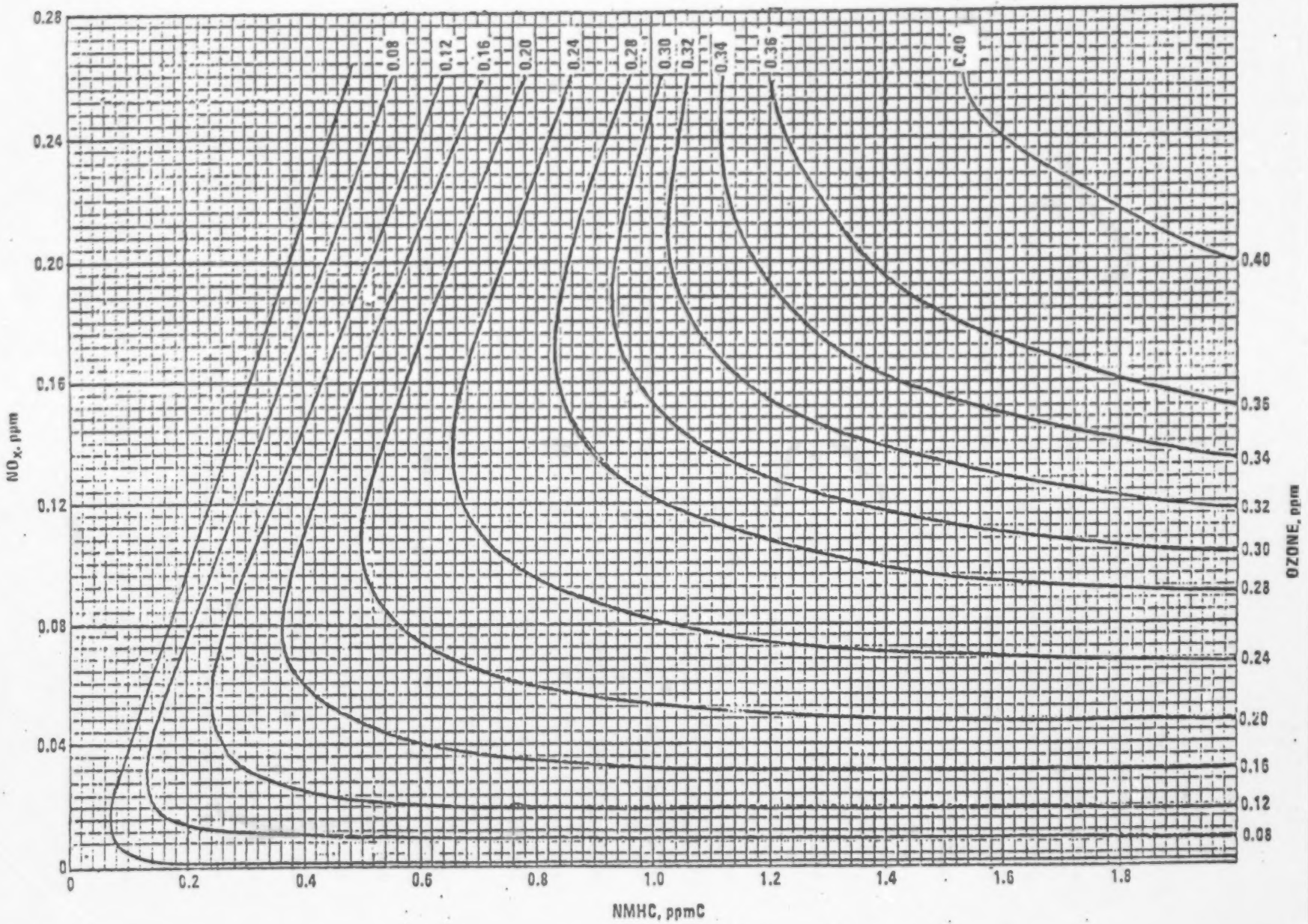

Figure E-1 Sensitivity of maximum afternoon ozone concentrations to morning precursor levels measured upwind.

in ozone levels. The reason for taking the second highest value as the design value is that the existing regulations on the ozone levels allow the standard concentration (0.08 ppm) to be exceeded once in a year and therefore exclude the highest value from consideration. The design values for various counties were provided by IEPA based on the 1977 monitoring data. The NMHC/NO_x ratios for Cook and Will counties were based on the actual monitoring data in these counties for 1976. As recommended by EPA, NMHC/NO_x ratio used was the median 6-9 a.m. ratio observed on the days having the five highest ozone values with accompanying NMHC and NO_x data.[1] In the case of other counties, the EPA recommended default value of 9.5 was used since the data available were not sufficient for an actual calculation of the NMHC/NO_x ratios. The changes in ozone levels associated with the corresponding changes in hydrocarbon emissions were analyzed based on the procedure recommended by EPA for EKMA for describing ozone/precursor relationship.[1] Final results are summarized in Table 2-1 in Section 2.

Appendix F

Population Affected by R77-3

Demographic data available from the Bureau of Census on each of the 21 affected counties are listed in Table F-1. The estimation of the total impacted population was based on the number of individuals within the 8 sample counties who would suffer a greater than negligible increase (below 0.1 percent) in ozone exposure if R77-3 was adopted. The results for the counties included in the sample analysis are presented in line 1 of Table F-2 for both the worst and the most probable case, as defined earlier in the report.

Based on the values in line 1 of Table F-2, it is estimated that, under the worst case conditions, with the adoption of the proposed regulation, 6,468,713 individuals living in the 8 sample counties would experience a greater than negligible increase in ozone exposure as measured by the data in Tables 2-2 and F-1, if R77-3 were adopted, than would have been the case if the existing regulations were strictly enforced. This number is obtained by adding the population figures from column 2 of Table F-1 on lines, 1, 2, 3, 4, 7, and 8. This is because, under the worst case conditions, it is estimated that Cook, Will, Jo Daviess, Peoria, Du Page, and Clark Counties will experience a greater than negligible increase in ozone levels. Similarly, it is estimated that 33,718 non-white individuals living in the 8 counties would experience an increase in ozone concentration greater than negligible under the most probable case if the proposed regulation were adopted. This figure is obtained by adding the values in column 5 of Table E-1

Table F-1

Population Breakdown for Counties Affected by R77-3

(1) County	(2) Total Population Number of People	(3) Population Under 15 Number of People	(4) Population Over 65 Number of People	(5) Population Non-White Number of People	(6) (3)/(2) x 100	(7) (4)/(2) x 100	(8) (5)/(2) x 100	(9) Median Age
1. Cook	5,493,766	1.544,812	518,134	1,251,473	28.1	9.4	22.8	29.1
2. Will	249,825	80,451	17,894	18,029	32.2	7.16	7.2	26.0
3. Jo Daviess	21,766	6,142	2,837	53	28.2	13.0	0.2	29.6
4. Peoria	195,318	57,948	21,208	15,624	29.7	10.9	8.0	28.8
5. St. Clair	285,176	95,688	25,862	64,408	33.6	9.1	22.6	26.8
6. Kankakee	97,250	22,398	10,585	11,415	23.0	10.9	11.7	28.8
7. DuPage	491,822	162,208	27,842	4,011	33	5.7	0.8	25.5
8. Clark	16,216	4,418	2,766	12	27.2	17.1	0.1	35.4
9. Kane	251,005	76,321	22,326	9,971	30.4	8.9	4.0	26.7
10. Marshall	13,302	4,035	1,839	13	30.3	13.8	0.1	32.0
11. Sangamon	161,335	48,365	18,818	8,826	30.0	11.7	5.5	30.3
12. LaSalle	111,409	33,953	13,731	858	30.5	12.3	0.8	31.0
13. Crawford	19,824	5,144	3,092	34	25.9	15.6	0.2	27.0
14. McHenry	111,555	35,378	10,249	338	31.7	9.2	0.3	27.5
15. Morgan	36,174	9,692	5,228	1,114	26.8	14.5	3.1	31.1
16. Madison	250,934	79,036	23,568	13,703	31.4	9.4	5.5	28.4
17. DeKalb	71,654	18,050	5,405	1,314	25.2	7.5	1.8	23.1
18. RockIsland	166,734	51,252	16,517	8,002	30.7	9.9	4.8	28.5
19. Douglas	18,997	6,767	2,213	78	35.6	1.9	0.4	30.8
20. Winnebago	246,623	81,103	21,301	16,758	32.9	8.6	6.8	26.7
21. Grundy	26,535	8,559	2,483	88	32.3	9.4	0.3	35.2
22. State Total	11,113,976	% under 18=34.2	% over 65=9.8	1,513,595				
23. Sum Lines 2-8	1,357,373	429,253	108,994	113,552				
24. Sum Lines 2-21	2,843,454	886,908	255,764	174,649				
25. (24)/(23)	2.09	2.07	2.35	1.58				

Source: Bureau of Census

Table F-2

Population Exposed to a Greater than Negligible (<0.1 percent) Increase in Ozone Concentration

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Worst Case				Most Probable Case			
	Suffering Increase in O_3 Concentration				Suffering Increase In O_3 Concentration			
	Number of People	Number of People 15 and Under	Number of People 65 and Over	Number of Non-Whites	Number of People	Number of People 15 and Under	Number of People 65 and Over	Number of Non-Whites
1.8 Counties	6,468,713	1,855,979	590,681	1,289,204	483,125	148,959	44,705	33,718
2.7 Counties (Not Cook)	974,947	311,167	72,547	37,731	483,125	148,959	44,705	33,718
3.20 Counties (not Cook)	2,037,639	644,116	170,485	59,615	1,009,731	308,345	105,057	53,274
4.21 Counties	7,531,405	2,188,928	688,619	1,311,088	1,009,731	308,345	105,057	53,274

on lines 2, 3, 4, and 8, referring respectively to Will, Joe Daviess, Peoria, and Clark Counties, where more than a negligible increase is expected under the most probable case.

Table F-3 repeats the presentation of data from Table F-2 with the exception that, instead of a greater than negligible increase in ozone concentration, the criterion is that there be a 3% or greater increase in ozone concentration. Consequently, population data from Clark County are used for the worst possible case as well as for the most probable case, since this is the only county estimated to experience an increase of 3% or greater in ozone concentration.

The data in line 1 of Tables F-2 and F-3 refer to the 8 sample counties. Many of the counties in the state do not contain sources that would be affected by the regulation, and therefore would not be expected to experience any change in ozone concentration. The counties on lines 9-21 of Table F-1 do contain sources affected by R77-3 but no emission data are availble for them. An average based on the first 8 counties of Table F-1 and applied to the remaining counties of Table F-1 would be very much dominated by data for Cook County. Consequently, it was decided to take an average of the population data on Lines 2-8 of Table F-1. In other words, we shall assume that both the population and ozone concentrations of Will, Jo Daviess, Peoria, St. Clair, Kankakee, DuPage, and Clark Counties taken together are representative of all 21 counties in the state that have pollution sources, with the exception of Cook County.

Table F-3

Population Exposed to 3% or Greater Increase in Ozone Concentration

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Worst Possible Case				Most Probable Case			
	Suffering Increase in O_3 Concentration				Suffering Increase In O_3 Concentration			
	Number of People	Number of People 15 and Under	Number of People 65 and Over	Number of Non-Whites	Number of People	Number of People 15 and Under	Number of People 65 and Over	Number of Non-Whites
1.8 Counties	16,216	4,418	2,766	12	16,216	4,418	2,766	12
2.7 Counties	16,216	4,418	2,766	18,041	16,216	4,418	2,766	12
3.20 Counties (Not Cook)	33,985	9,145	6,500	19	33,985	9,145	6,500	19
4.21 Counties	33,985	9,145	6,500	19	33,985	9,145	6,500	19

The data of Table F-1 are arranged so that lines 23 and 24 simply sum the demographic data over, in the first instance, the 7 counties, Will, Jo Daviess, Peoria, St. Clair, Kankakee, Du Page, and Clark, and, in the second instance, over all the counties which have sources, except for Cook. Line 25, then, is the device used to project information about numbers of people exposed to varying levels of ozone pollution for the 7 counties on which data are obtainable (again excluding Cook) to the rest of the counties in the state that have sources affected by the regulation (again excluding Cook). Thus, line 2 of Table F-2 gives the number of people in the 7 counties and in different population categories for both the worst case and the most probable case who are expected to suffer an increase in ozone concentration greater than negligible. These data are simply multiplied by the value in line 25 of Table F-1 to obtain an estimate of the number of people in the 20 counties experiencing an increase in ozone concentration greater than negligible, but again excluding Cook County. Finally, line 4 provides an estimate over all 21 counties, including Cook, of the people in various population categories who experience an increase in ozone concentration greater than negligible under both the worst and most probable cases. This line can be taken to represent a statewide estimate, since it has been assumed that there will be no change in ozone concentration due to the regulation in those counties where no sources affected by the regulation exist. Table F-3 repeats the information of Table E-2 but in this case for a 3% or greater increase in ozone concentration. Here notice that lines 1 and 2 and lines 3 and 4 of the Table are the same, since Cook County is not expected to experience an increase in ozone concentration, even under the worst case of 3% or greater.